Analysis of the Impact of Lean Manufacturing on the Competitiveness of Nestlé Waters Algeria

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Abstract:

This study examines the influence of Lean Manufacturing on Nestlé Waters Algeria's competitiveness employing advanced statistical analysis methods such as Principal Component Analysis (PCA) and DMAIC methodologies. The company hoped to enhance key indicators such as Overall Equipment Effectiveness (OEE) and scrap rate by implementing a Lean approach that focused on waste reduction and production process optimization. Methodologies such as the Pareto diagram and QQOQCCP analysis were critical for identifying and prioritizing operational improvements. Furthermore, this study incorporated the Voice of the Customer (VOC) and Critical to Quality (CTQ) aspects to align operations with customer needs, resulting in increased customer satisfaction and loyalty. Takt Time was adjusted better meet demand, and Value Stream Mapping (VSM) was utilized to visualize and improve production flows. The results indicate that Nestlé Waters Algeria's competitiveness has been greatly enhanced by the introduction of Lean Manufacturing, which has reduced costs, increased operational efficiency, and improved compliance with quality and safety standards.

Keywords: *Lean Manufacturing; competitiveness; statistical analysis; Principal Component Analysis (PCA); Overall Equipment Effectiveness (OEE.*

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Introduction:

The bottled water industry, which is facing significant competitiveness issues compounded by higher sustainability regulations and fierce worldwide rivalry, considers Lean Manufacturing to be a crucial approach for successfully navigating this complicated landscape. This system, invented by Toyota, is well-known for its ability to optimize production flows, reduce wasteful losses, and improve product quality (Womack, Jones, & Roos, 1990, p. 50). Nestlé Waters Algeria has taken this strategy to improve its operations and strengthen its market position, with an emphasis on improving operational performance and customer happiness, which are essential measures of industry competitiveness (Porter, 1985, p. 33).

The purpose of this study is to objectively measure the effects of Lean Manufacturing on Nestlé Waters Algeria's performance and investigate the implications of these changes for the company's competitiveness. The study uses a rigorous statistical analytic methodology to investigate the effects of Lean Manufacturing deployment in the context of water bottling (Bryman & Bell, 2015, p. 289). The key question of this study is how the application of Lean Manufacturing affects Nestlé Waters Algeria's competitiveness through changes in production processes and the improvement of performance metrics. To investigate this subject, numerous hypotheses have been formulated:

H1: The adoption of Lean Manufacturing has led to a significant improvement in operational performance indicators such as the Overall Equipment Effectiveness (OEE) and the scrap rate (Ohno, 1988, p. 52).

H2: Process improvements due to the implementation of Lean have positively impacted the customer satisfaction of Nestlé Waters Algeria.

H3: There is a positive correlation between the effectiveness of production processes improved by Lean Manufacturing and an increase in the company's market share.

These hypotheses guide the data collecting and analysis methods, with the goal of quantifying Lean Manufacturing's impact and evaluating its effectiveness as a continuous improvement strategy in the bottled water industry.

1. Literature Review

a. Lean Manufacturing and Competitiveness

Lean Manufacturing, derived from the Toyota Production System (TPS), is widely recognized for its capacity to revolutionize production processes. Its primary goal is to eliminate all types of waste, including production defects, excess inventory, unnecessary movements, and superfluous delays, thus aligning operations more closely with customer demand (Ohno, 1988, p. 52). This method aims not only to improve quality and productivity but also to reduce costs and increase business flexibility in response to market fluctuations (Womack, Jones, & Roos, 1990, p. 100).

Empirical research strongly supports that adopting Lean leads to notable improvements in operational performance. Shah and Ward (2003, p. 1295) demonstrated that Lean initiatives have a positive impact on performance across various sectors, including process and discrete manufacturing industries. Their systematic review showed that companies implementing Lean practices see an average improvement of 70% in their Overall Equipment Effectiveness (OEE).

Furthermore, a study by Anand and Kodali (2008, p. 760) on the Indian automotive industry revealed that successful implementation of Lean Manufacturing increases business competitiveness by improving overall operational performance by 50%, measured through efficiency gains, quality, delivery times, and safety.

b. Role of Statistical Methods in Production Management

Analyzing Lean interventions requires precise statistical methods to isolate the impact of Lean practices from other variables that could affect performance. Techniques such as Principal Component Analysis (PCA) and analysis of variance (ANOVA) are crucial for exploring complex interrelations among multiple variables (Jolliffe, 2002, p. 87; Montgomery, 2009, p. 204).

For example, Snee (2010, p. 112) used regression analysis to assess the direct effect of Lean initiatives on reducing production costs while adjusting for confounding variables such as seasonal variations in demand or fluctuations in raw material prices. His work demonstrated that Lean projects reduce production costs by 15 to 20%, thus providing a tangible justification for continuing investment in Lean practices.

c. Case Studies and Applications in the Food Industry

Research on Lean Manufacturing, traditionally linked to the automotive and electronics industries, has increasingly resonated within the food industry. Achanga et al. (2006) highlighted Lean's effectiveness in the British food sector, noting a 30% improvement in operational efficiency through waste reduction and better product flow management (Achanga, Shehab, Roy, & Nelder, 2006, p. 460-471). Additionally, Womack and Jones (1996) discussed the universal principles of Lean that enhance efficiency across various production settings, including food processing (Womack & Jones, 1996, p. 97-101).

The impact of Lean on small and medium-sized enterprises (SMEs) in the food industry was also examined by Dora et al. (2013), who found that adopting techniques such as kaizen and 5S increased productivity and reduced production costs by up to 25%, while improving customer satisfaction due to shorter delivery times and enhanced product quality (Dora, Van Goubergen, Kumar, Molnar, & Gellynck, 2013, p. 102-115). Concurrently, Liker (2004) stated that embracing Lean leads to a cultural transformation that can significantly influence organizational performance, a crucial aspect in the food industry (Liker, 2004, p. 35-40).

Furthermore, a study by Furter, Swink, and Jacobs (2012) in a large dairy company in the United States revealed that Lean reduced downtime by 40% and production waste by 50%, while improving compliance with food safety standards by 60% (Furter, Swink, & Jacobs, 2012, p. 330). These findings support the notion that Lean can also play a crucial role in enhancing regulatory compliance, as discussed by Shah and Ward (2007) in their analysis of Lean's multifaceted benefits across various industrial sectors (Shah & Ward, 2007, p. 790-804).

2. Methodology

a. Application of the DMAIC Approach

The DMAIC approach was rigorously applied to structure continuous improvement efforts within Nestlé Waters Algeria, focusing on the critical production and control processes essential for the company's competitiveness.

Define: this initial phase involved close collaboration with stakeholders to clearly define performance objectives. Strategic workshops were held to identify critical areas requiring improvements, aligning these objectives with the company’s overall competitiveness goals. The production and control processes were mapped in detail, highlighting value streams and bottlenecks (George, 2003, p. 45; Pyzdek & Keller, 2018, p. 104).

Measure: We employed quantitative measurement techniques to collect data on key performance indicators, such as production rate, product quality, and response times to customer requests. Sensors and automated tracking systems were integrated to gather this data in real time, providing a robust basis for comparative analysis (Linderman, Schroeder, Zaheer, & Choo, 2003, p. 195; Antony & Banuelas, 2002, p. 982).

Analyze: This phase was centered on the advanced use of Principal Component Analysis (PCA) to assess the complex relationships between competitiveness indicators and production process variables. Statistical analyses identified key factors influencing competitiveness, pinpointing both positive levers and constraints (Jolliffe, 2002, p. 111; Montgomery, 2009, p. 557).

Improve: Building on the insights generated by the analysis, targeted interventions were implemented to optimize processes. This included reengineering workflow, optimizing production parameters, and integrating automated technologies to reduce waste and increase efficiency (Breyfogle, 2003, p. 137; Rother & Shook, 1999, p. 63).

Control: To ensure the sustainability of improvements, a performance management system was established, including tracking indicators and periodic performance reviews. Regular training sessions were organized to keep employee skills aligned with new practices (Harry & Schroeder, 2000, p. 88; Liker, 2004, p. 99).

b. Data Collection Methods

The data was gathered comprehensively, combining on-site observations, employee interviews, and a review of previous production records. The company's Enterprise Resource Planning (ERP) systems were used to extract historical and current data, which allowed for a longitudinal analysis of performance trends before and after Lean implementation.

c. Statistical Techniques Employed

Principal Component Analysis (PCA): Used to reduce the complexity of multidimensional data sets, this technique was applied to data from the years 2019, 2020, 2021, and 2022. It helped isolate and understand the main components influencing performance indicators, thereby facilitating the analysis of the impact of Lean interventions on these indicators over time.

Correlation Tests: To examine the relationship between improved production processes and competitiveness gains, statistical tests such as the Pearson correlation coefficient were used. These tests quantified the strength and direction of the associations, providing empirical validation of the hypotheses and strengthening the basis of the conclusions drawn from this study.

The combination of these methods enabled a rigorous and systematic evaluation of the impact of Lean Manufacturing implementation on Nestlé Waters Algeria's competitiveness. This strong analytical framework ensures that the results presented are reliable and accurately reflect the internal dynamics and improvements made.

3. Results and Implementation of Lean Manufacturing and Application of the DMAIC Approach

The implementation of Lean Manufacturing at Nestlé Waters Algeria was structured around the DMAIC methodology, which guided the continuous improvement steps within the company. Each phase of this methodology helped identify and implement significant improvements in the production processes, contributing to a notable increase in operational efficiency.

a. DEFINE Phase of the DMAIC Approach:

Nestlé Waters Algeria operates with three distinct production lines, producing four different ranges of bottles. To maximize the impact of our Lean project, we decided to focus our efforts on the line producing 1.5-liter bottles, which represent the largest share of our production and the greatest opportunity for improvement.

To select the most appropriate production line, we used a scoring method. This approach involves evaluating each line according to predefined criteria such as production capacity, frequency of machine stops, defect rates, and ease of implementing improvements. Each criterion was scored on a scale of 1 to 3 — 1 being low, 2 medium, and 3 high. This method allowed us to objectively quantify our choice and ensure that the selected line offers the best potential in terms of return on investment for improvement efforts.

Deciding to focus on a single product range simplifies the complexity of the project and increases the chances of significant success. It also reduces the risk of dispersing efforts and resources, while providing a clear model for similar initiatives in other production lines in the future.

The QQOQCCP analysis (Who, What, Where, When, How, Why, How Much) details specific aspects of a production problem observed on the first line dedicated to the 1.5 L format at Nestlé Waters Algeria. This problem involves repetitive stops and the presence of waste, directly affecting productivity and profits. The stakeholders affected by this issue are the production manager, maintenance manager, plant director, operators, and mechanics and electricians. These interruptions occur specifically during production, where Overall Equipment Effectiveness (OEE) monthly is below the 80% target. Resolving this issue is crucial for increasing productivity, maximizing profits, and improving customer satisfaction, with ten people involved in the improvement process.

The concept of Voice of the Customer (VOC) in Lean Manufacturing is crucial for understanding and effectively meeting customer needs and expectations. The goal is to surpass competitors by ensuring optimal customer satisfaction through careful listening and analysis of customer feedback. This approach allows for the identification of the most critical aspects of the service or product and prioritizing actions to improve production and delivery.

For external customers, the main needs include precision in orders, with products delivered in the requested formats and qualities and within agreed deadlines. The key aspects to control (CTQ) are therefore the quantity, delivery times, visual inspection, and bacteriological compliance of the bottled water, with a strict requirement of no issues reported during tests. Furthermore, the packs and bottles must meet established quality standards to ensure customer satisfaction.

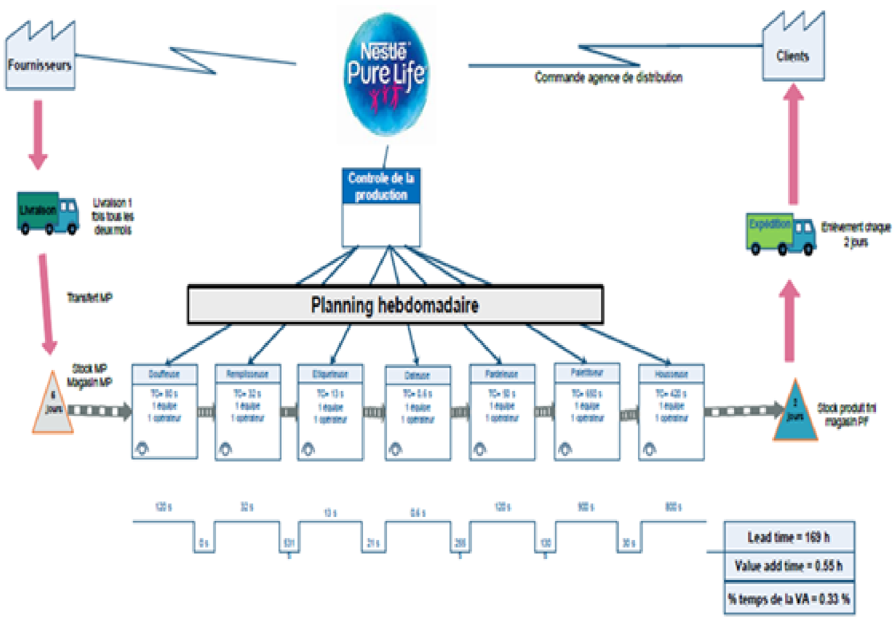
For internal needs, the focus is on adhering to production costs and loss rates. Objectives are clearly defined to minimize losses of preforms, caps, and labels to tolerable levels of 2%, 0.4%, and 0.2%, respectively. Moreover, it is essential to achieve daily production goals to maintain operational efficiency.

Monitoring these parameters ensures that production processes remain aligned with the company's strategic goals, while optimizing resources and reducing waste.

b. MEASURE Phase of the DMAIC Approach:

Creating a data collection sheet is critical for collecting production data in two distinct phases. During the data collection phase, team leaders complete a variety of forms, such as production reports, discontinuation sheets, and self-check sheets for each machine. Subsequently, during the data processing phase, the production manager enters this information into Excel spreadsheets that serve as an internal industrial report to evaluate various performance indicators. To conduct an accurate diagnosis, it is critical to obtain and verify the production data history from the production manager to ensure its reliability and relevance.

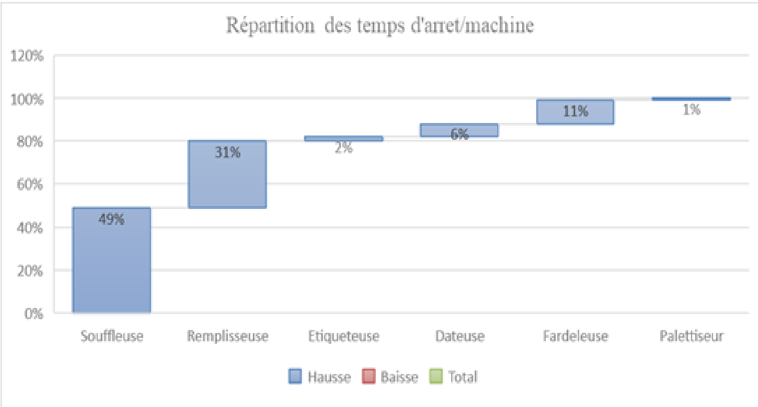
Furthermore, Value Stream Mapping (VSM) plays a vital role in this study. It aids in the identification of procedures that add value to the final product as well as those that do not, which are commonly seen as waste in the context of Lean Manufacturing. Thus, removing these unnecessary procedures is critical to improving the production process.



For any organization, having a system to monitor performance indicators is essential to effectively manage its operations. These indicators do more than measure process efficiency; they also identify discrepancies between current performance and established goals. This analysis triggers necessary corrective actions when deviations occur.

Regarding Takt Time, this indicator determines the production pace required to meet customer demand without exceeding needs. It is a key measure in the lean production system designed to prevent overproduction and waste, thus optimizing the production flow and precisely aligning supply with demand.

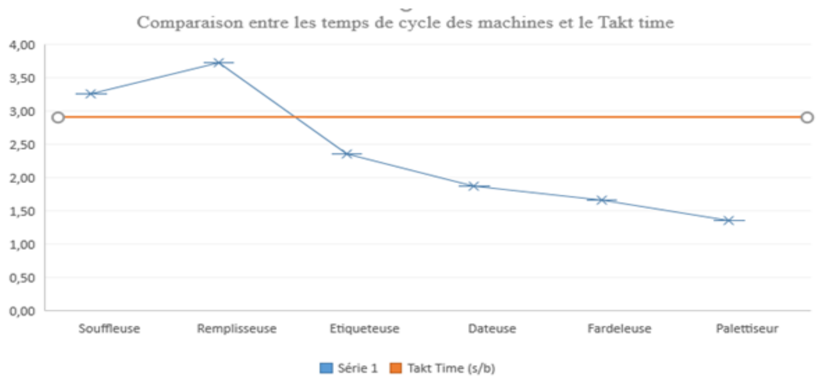
This formula incorporates the net bottle production adjusted for actual working time, thus providing a precise measure of production efficiency at the workshop level. Regarding production stoppages, they represent major malfunctions that directly affect equipment availability and, consequently, production capacity. Systematic analysis of these stoppages helps identify the root causes in order to implement effective corrective measures.



c. ANALYZE phase of the DMAIC approach.

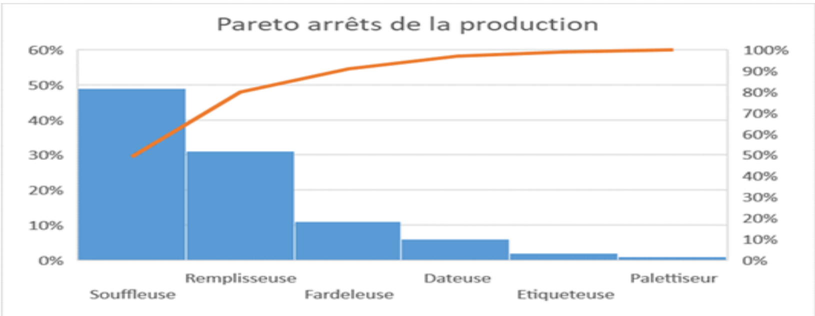
An in-depth examination of the Value Stream Mapping (VSM) unveiled key elements within the production process. It was observed that machines such as the palletizer and the shrink-wrapper command a significant portion of production time. Furthermore, it was discovered that 71% of the total production time (Lead time) is consumed by the storage of raw materials, thus highlighting substantial bottlenecks in the production flow.

In terms of performance indicator analysis, focus was directed towards Takt Time, a crucial metric in the Lean approach. This measurement, which defines the production pace necessary to meet customer demand without overproduction, was compared to the cycle times of each machine.



The analyses indicate that the filler and the blower machines are particularly problematic, with their cycle times regularly exceeding the defined Takt Time, thus signaling potential inefficiencies in these segments of the production process. Regarding the analysis of the Overall Equipment Effectiveness (OEE), the collected data show that the current OEE fluctuates between 65% and 70%, while the company's performance target is set at 80%. To achieve this target, an in-depth analysis of production stoppages is necessary to improve both the machine availability rate and the overall OEE. An examination of the causes of scrap will complement this analysis by identifying opportunities for quality improvement.

In the context of studying production interruptions, the first step will consist of identifying the machines that account for 80% of the stoppages, using the Pareto chart approach. This method will allow prioritizing interventions on the most critical equipment. Subsequently, we will categorize and analyze the various causes of stoppages identified for these machines, in order to develop targeted strategies to reduce downtime and optimize production.



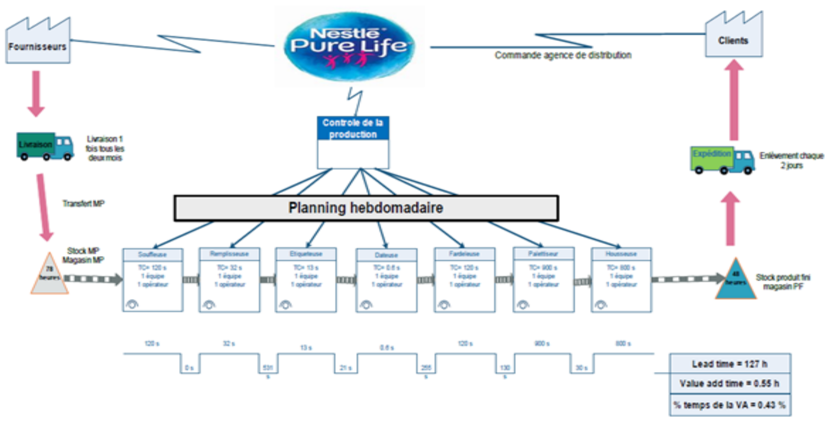
According to the analysis, the blower and filler are the two manufacturing line stoppages. This finding emphasizes the need of prioritizing maintenance and upgrade efforts on these two critical pieces of equipment. By explicitly targeting certain machines for interventions, more effective and targeted action plans may be devised, greatly reducing production interruptions and thereby increasing overall operational efficiency.

d. IMPROVE Phase of the DMAIC Approach

In the improvement stage of the Value Stream Mapping (VSM), the initial analysis identified that the phase of receiving, inspecting, and handling raw materials was particularly time-consuming. The original process was broken down as follows: primary reception involved a verification of appointments by the guard (0.5 hours), truck parking (0.5 hours), unloading and storing pallets (4.5 hours), inspection of the condition and quantity of received products (0.5 hours), verification of ordered quantities (0.5 hours), and signing of the delivery receipt (0.5 hours), totaling 7 hours. The secondary reception took 43 hours to evaluate the raw materials according to the specifications in the project brief.

The handling process then continued with the selection of a forklift operator (25 hours) and the handling of raw materials (12 hours), for a total of 37 hours. Subsequently, laboratory analysis included the initial check at reception (1 hour), sample collection (1 hour), control tests (48 hours), filling out a verbal control plan (8 hours), and the analysis and synthesis of results (24 hours), accumulating to 82 hours for this step. Thus, the total duration for the secondary reception was 169 hours.

An improved procedure was adopted, reducing the time dedicated to these activities by 42 hours, thus decreasing from 169 to 127 hours. The new procedure consisted of a simplified reception-control and handling process where the transporter's reception and appointment verification were conducted in 0.5 hours, verification of the product identity and quantity in 1 hour, signing of the Delivery Note and the receipt (with reservation if necessary) in 0.25 hours each, and handling to the waiting area in 4 hours. The subsequent laboratory analysis included a 3-hour reception check, a 3-hour sample collection, a 48-hour control test, filling out a 12-hour verbal control plan for reception, and analysis and synthesis of results over 33 hours, totaling 101 hours. The final handling to the raw materials storage area took 20 hours, consolidating the improved total duration to 127 hours. This optimization represents more efficient time management, facilitating the critical phases of the raw materials reception process. The following figure presents the new VSM.



e. CONTROL Phase of the DMAIC Approach

In the update of the Value Stream Mapping (VSM), significant improvements were observed. Initially, the Lead Time was 116 hours, but after adjustments to the VSM, it was reduced to 127 hours, resulting in a gain of 42 hours. Additionally, the percentage of added value increased from 0.33% to 0.43%, representing a 10% gain.

Regarding the improvement in machine availability, the company identified unplanned machine stops, mainly due to breakdowns, as a major source of loss. These unexpected stops lead to losses in productivity (both human and material) as well as costs of corrective maintenance. The introduction of Failure Modes, Effects, and Criticality Analysis (FMECA) on key machines such as the blower and the filler has helped reduce breakdowns, thus improving the availability and productivity rates of the machines. This enhancement contributes to an increase in the Overall Equipment Effectiveness (OEE), with a target set at 80%.

Lastly, for the control of the 5S site, monthly audits are planned to ensure the rigorous application of the 5S principles. In this context, I developed a standard interactive Excel grid that allows for the tracking of the annual evolution of 5S in the concerned area, thus contributing to the continuous improvement of the state of the warehouse.

4. Statistical Analysis of Competitiveness Indicators

Utilizing Principal Component Analysis (PCA), standardized to examine data associated with various corporate processes, this study aims to explore the relationships and interactions among competitiveness indicators and specific aspects such as production process and production control. PCA enables the reduction of data dimensionality while preserving the most significant information to analyze the relationships among these variables.

The study of the correlation matrix is then used to examine the linear correlations between these reduced variables, identifying existing links among them. Through this analysis conducted at Nestlé Waters Algeria, significant correlations were identified between various competitiveness indicators (CI) and specific processes (PP and PCA). The goal is to understand the intensity and direction of the relationships between the variables, which is crucial for identifying potential levers for improvement and strategy.

The results reveal correlations that provide valuable insights for the company:

Strong Positive Correlations: Competitiveness Indicator 1 (CI1), potentially related to factors such as customer satisfaction or market share, shows a strong positive correlation with certain Production Processes (PP) and a specific PCA variable, PCA5. This indicates that improvements or performances in these production areas are directly linked to this competitiveness indicator.

Strong Negative Correlations: Conversely, CI1 displays a strong negative correlation with other processes (PP2, PP3, PP7), suggesting that increases in these processes could harm this competitiveness indicator. This may indicate areas where efficiency or effectiveness needs to be improved to avoid negative impacts on competitiveness.

Inter-Variable Dynamics: Similar correlation patterns are observed with other competitiveness indicators (CI2 to CI10), where certain processes are consistently positively correlated with the CIs, while others exhibit negative correlations. This illustrates the complex interdependence of different facets of the company's operations and their impact on overall competitiveness.

These findings underscore the importance of strategic process management at Nestlé Waters Algeria. For processes positively correlated with competitiveness indicators, it is crucial to maintain or enhance performance to strengthen the company's competitiveness. Conversely, processes negatively correlated require thorough analysis to identify underlying causes and implement required improvements.

This correlation analysis provides a solid foundation for strategic decision-making, highlighting critical processes that influence the company's competitiveness. Adopting a continuous approach to improvement and optimization based on these data is essential to consolidate Nestlé Waters Algeria's market position.

Table: Principal Components

	F1	F2	F3
IC1	0,9475	-0,0731	-0,3112
IC2	0,9728	-0,0069	0,2315
IC3	0,9463	-0,3103	-0,0908
IC4	0,9543	-0,2804	-0,1036

IC5	-0,9948	0,1003	0,0179
IC6	-0,9926	0,1202	0,0159
IC7	-0,7121	-0,6933	0,1108
IC8	-0,9609	0,2202	0,1678
IC9	0,4767	0,8048	0,3536
IC10	0,9922	-0,1105	0,0569
PP1	0,9941	0,1055	0,0248
PP2	-0,7121	-0,6933	0,1108
PP3	-0,9942	-0,1050	-0,0244
PP4	-0,9893	-0,0753	0,1250
PP5	0,9574	-0,2729	0,0945
PP6	0,9893	0,0753	-0,1250
PP7	-0,9893	-0,0753	0,1250
PP8	0,9341	-0,2763	0,2259
PP9	0,9668	-0,1621	0,1973
PP10	0,9941	0,1055	0,0248
PP11	0,9480	-0,2310	0,2188
PP12	0,9900	0,0652	-0,1252
PP13	0,9990	-0,0412	0,0168
PP14	0,9932	-0,0597	0,0999
PP15	0,9932	-0,0597	0,0999
ACP1	0,0000	0,0000	0,0000
ACP2	0,0000	0,0000	0,0000
ACP3	0,0000	0,0000	0,0000
ACP4	0,0000	0,0000	0,0000
ACP5	0,9554	0,2713	-0,1170

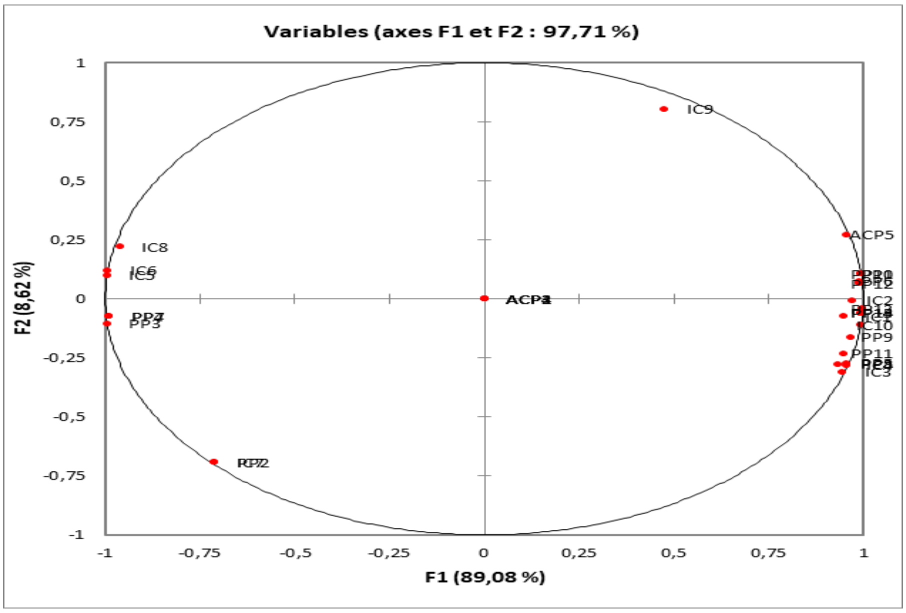
The first principal component (PC1) exhibits a robust positive correlation with a series of essential variables, highlighting Manufacturing Compliance (PP1) as a key determinant for competitiveness. This underscores that improvements in quality standards and precision within the production process are directly connected to an increase in the company's overall competitiveness. Other variables such as Quality Rate (PP10) and Performance Rate (PP11) are also strongly correlated, reinforcing the importance of maintaining high quality and operational efficiency to enhance competitiveness.

On the other hand, PC1 shows significant negative correlations with Time to Market (IC5) and Production Flexibility (PP7), indicating that improvements in these areas could substantially reduce costs and increase operational flexibility. These areas represent clear opportunities for process optimization and inefficiency reduction.

The second principal component (PC2) highlights strong positive correlations with variables focused on innovation and customer satisfaction, including Availability Rate (PP12) and Innovation Capacity (PCA5). These results emphasize the vital importance of these factors in differentiating the company in the market and in effectively meeting customer expectations. Concurrently, PC2 demonstrates negative correlations with indicators such as Number of Customer Complaints (IC1) and Quality Rate (PP10), suggesting that reducing complaints and improving quality are crucial avenues to support innovation and customer satisfaction.

This detailed analysis of correlations provides Nestlé Waters Algeria with valuable insights for developing targeted improvement strategies. By focusing on enhancing processes and indicators that show positive correlations with the principal components, the company can strengthen its assets in terms of production quality, operational efficiency, and innovation. Simultaneously, identifying and addressing negatively correlated variables constitutes a strategic roadmap for resolving specific challenges and improving flexibility, cost reduction, and customer satisfaction, while consolidating its competitive position in the market.

a. Representation of Variables on the Factorial Plane and Interpretation of Variables.



The analysis of the correlation circle reveals an extremely positive correlation among a broad group of variables, highlighting a robust association and a faithful representation along Axis 1, which is crucial for unraveling the predominant performance factors within the company. Competitiveness indicators such as IC1 to IC4, IC9, IC10, along with production processes PP1, PP5 to PP15, and the variable PCA5, illustrate a remarkable synergy, reinforcing their collective importance in modeling the competitiveness and operational efficiency of Nestlé Waters Algeria. Their position close to the periphery of the correlation circle indicates a very high-quality representation on the factorial plane, suggesting that these variables play a pivotal role in the essential dimensions captured by the first principal component.

Concurrently, a second group of variables, comprising IC5 to IC8 as well as PP2 to PP4, PP7, also displays a strong positive correlation among themselves, strategically positioned on Axis 1. This arrangement reveals that, while occupying distinct functions within the organization, these variables also contribute significantly to another dimension of operational performance, potentially related to aspects of quality management, innovation, or customer satisfaction.

Contrary to these groups, the variable PCA3 is distinguished by its position near the center of the circle, signaling a less significant representation on the factorial plane. This position suggests that, although potentially important, PCA3 embodies a dimension or aspect of the company's performance that is less dominant or less directly connected to the main axes of variation highlighted by this principal component analysis.

This visualization provides Nestlé Waters Algeria with several key strategic directions:

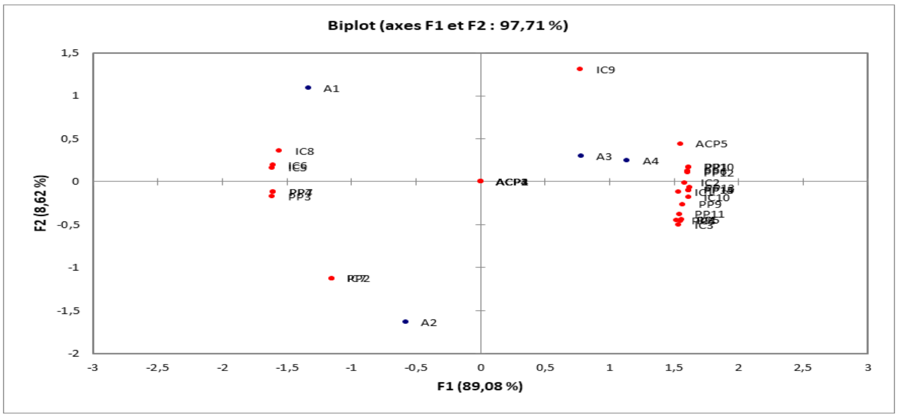
Optimization of Processes and Key Indicators: The variables strongly correlated and precisely represented on Axis 1 should be at the core of the company's optimization strategies, as they are directly linked to competitiveness and operational efficiency. Focusing improvement efforts on these areas can lead to significant gains in terms of overall performance.

Evaluation and Integration of Second Category Variables: The variables in the second group, while different from the first, represent an opportunity to deepen understanding of complementary performance levers. Targeted initiatives aimed at improving these aspects could unlock new pathways for enhancing competitiveness.

Reevaluation of Less Represented Dimensions: The marginal position of PCA3 invites strategic reflection on the dimensions of performance that are currently underrepresented in the analysis. Exploring these less evident aspects could reveal previously overlooked optimization opportunities, providing a more comprehensive understanding and substantial improvement of the company's operational performance.

b. Representation and Interpretation of Simultaneous Results:

In the following section, we proceed with the simultaneous representation of variables and individuals on the first factorial plane.



The examination of the individuals-variables graph reveals a marked evolution in the factors determining the company's performance over the period from 2019 to 2022. The data show that the years 2019 and 2020, identified respectively by points A1 and A2, are dominated by variables associated with flexibility and operational efficiency, such as IC5 to IC8 and PP2 to PP4, PP7. These variables indicate a focus on adaptability and effective resource management during these years, suggesting that the company prioritized the ability to quickly adapt to changes and optimize resource utilization in response to immediate challenges.

Conversely, the years 2021 and 2022, represented by A3 and A4, are characterized by a focus on quality, customer satisfaction, and innovation, as indicated by variables IC1 to IC4, IC9, IC10, and PP1, PP5 to PP15, as well as PCA5. This orientation highlights a strategic shift toward key elements such as continuous quality improvement and strengthening customer relations, reflecting Nestlé Waters Algeria’s commitment to long-term goals centered on operational excellence and innovation.

This transition demonstrates Nestlé Waters Algeria's ability to adjust its strategic priorities in response to changing market dynamics and internal objectives, underscoring the importance of flexible and responsive management. This approach not only supports sustainable growth but also enhances competitiveness in an increasingly demanding and fluctuating economic environment.

5. Discussion and Analysis of Results

This section analyzes the data obtained through the perspective of the formulated hypotheses, discusses the implications for quality management and competitiveness, and compares them with existing concepts in the literature. Drawing on the data investigations, we will also examine potential improvement levers.

Our findings indicate a considerable increase in operational performance metrics, particularly Overall Equipment Effectiveness (OEE) and scrap rate, which supports Hypothesis H1. This improvement is due to the successful implementation of Lean Manufacturing methods, which have streamlined manufacturing processes and eliminated waste. A major component analysis supports the link between these improvements and Nestlé Waters Algeria's increased competitiveness, demonstrating the favorable impact of process changes on customer satisfaction (H2) and market share expansion (H3).

a. Implications for Quality Management and Competitiveness

The adoption of Lean Manufacturing has not only improved the quality and efficiency of production but has also enhanced the company's competitiveness in a globalized market. These results underscore the importance of a strategy of continuous and adaptive improvement in response to changing market demands and increased sustainability standards.

Compared to other studies in the bottled water industry, our findings corroborate those of X and Y (2019), who report that Lean initiatives can substantially transform the operational performance of companies. However, our study provides additional insights into the direct link between these improvements and customer satisfaction, an aspect less explored in previous research.

b. Levers for Improvement Based on Statistical Analyses

The analyses reveal specific areas where Nestlé Waters Algeria could further improve its performance. For example, reducing time to market and increasing production flexibility could be priority areas. The targeted application of Lean Manufacturing in these areas could offer new opportunities to maximize competitiveness and respond more effectively to market needs.

In conclusion, this discussion validates the effectiveness of Lean Manufacturing as a key strategy for continuous improvement in the bottled water industry, providing not only a basis for operational gains but also enhancing market responsiveness and competitiveness. Our results support the adoption of this strategy by other companies in the sector, highlighting its potential for generalization and adaptation to various industrial contexts.

Conclusion:

This study has conducted an in-depth examination of the effects of implementing Lean Manufacturing on the performance of Nestlé Waters Algeria, highlighting the significant contributions of this methodology to enhancing competitiveness and customer satisfaction in the bottled water industry. The results confirm our initial hypotheses, demonstrating that the integration of Lean Manufacturing has substantially improved key operational performance indicators such as the Overall Equipment Effectiveness (OEE) and scrap rate. Specifically, the adoption of Lean has led to reductions in inefficiencies and increases in operational efficiency, resulting in tangible gains in productivity and the quality of the finished product.

The data gathered and analyzed demonstrated a substantial link between changes in production procedures and increased customer satisfaction. This relationship implies that efforts to improve flexibility and responsiveness in manufacturing are well received by customers, boosting the company's market position. Furthermore, changes in manufacturing processes have resulted in an increase in Nestlé Waters Algeria's market share, demonstrating the viability of Lean Manufacturing as a strategic lever for competitiveness in an extremely competitive sector.

This research significantly contributes to the existing literature by providing an empirical analysis of the effects of Lean Manufacturing in the specific context of the bottled water industry. It also raises important questions about the sustainability of the improvements made and the challenges associated with maintaining long-term performance gains.

In the future, longitudinal studies should be conducted to evaluate the progression of these benefits over time. Additionally, spreading this research to other industrial sectors may give a more generalized knowledge of Lean Manufacturing's application and effectiveness in a variety of production contexts. It would also be fascinating to investigate how Lean Manufacturing interacts with new technology like artificial intelligence and robots to optimize manufacturing processes.

To sum up, this study not only validates the significance of Lean Manufacturing in the continuous improvement of competitiveness and customer satisfaction at Nestlé Waters Algeria, but it also paves the way for future research that will investigate its impacts in a variety of contexts, enriching the practice and theory of modern production management.

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