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Production model based on Lean Manufacturing-TPM to increase the service level in a SME in the food sector

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Abstract*– This article provides a comprehensive exploration of the challenges faced by a company operating in Peru's competitive food industry, specifically within the "Sauces, Dressings, and Condiments" category. The selected company grapples with issues related to service levels, productivity, and efficiency, necessitating strategic interventions for improvement. With a targeted approach to address these challenges, the research proposes the implementation of Total Productive Maintenance (TPM) and Lean Manufacturing to significantly enhance the company's operational performance, placing a particular emphasis on mitigating inefficiencies within the packaging area. Insights into the principles of these tools are provided, showcasing their potential positive impacts on operational efficiency in similar contexts. The article introduces a carefully crafted model, centered around standardized work and TPM, aimed at enhancing the company's service levels. This model unfolds through stages, including problem analysis, tool implementation, and validation. Simulation results demonstrate a tangible potential increase in service levels from 83% to 94.2%, accompanied by notable improvements in Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR). While the achieved results fall slightly short of the initially set goals, they underscore significant progress and signal the potential for further refinement, affirming the effectiveness of Lean Manufacturing and TPM in elevating the specific company's operational performance within the dynamic and competitive landscape of the food sector.

Keywords—Service Level, Lean Manufacturing, TPM, Food Sector

I. INTRODUCTION

The manufacturing sector in Peru plays a pivotal role in the country's economy, experiencing consistent growth over recent years and contributing significantly to economic development. The industrial manufacturing production increased by 17.9% in 2021 compared to 2020, and 3% compared to 2019, driven by the non-primary subsector [1]. This subsector's performance, influenced by increased production of consumer and intermediate goods, has propelled the overall growth of the manufacturing sector.

Within the manufacturing sector, the food industry stands out as a crucial component, encompassing the production of food products. The selected company for this study operates in the branch of food product manufacturing. This sector not only generates substantial employment, particularly in production, logistics, and maintenance but also contributes significantly to Peru's GDP. In the third quarter of 2021, manufacturing represented 15.3% of the GDP, with the food sector alone employing over 560,000 people, constituting 18% of the country's manufacturing employment. Furthermore, the food industry in Peru has demonstrated remarkable growth, making it the second-largest export sector in 2021, following the mining sector.

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The company under examination belongs to the "Sauces, Dressings, and Condiments" category in Peru, operating in a market that has witnessed a steady growth of 20.6% in 2021 compared to 2020. Despite facing stiff competition from industry leaders like Alicorp, Ajinomoto, and Nestlé, the company strives for continuous development and growth within the food industry.

This article delves into the background of the selected company, analyzing the manufacturing sector in Peru, its growth trajectory, and the challenges it faces, with a specific focus on issues such as service levels, productivity, and efficiency. The subsequent sections will explore the identified problems in the industry and potential solutions, considering previous research findings and industry benchmarks. The goal is to provide insights and recommendations that can contribute to the company's efforts to enhance its operational performance in this dynamic and competitive sector.

II. STATE OF ART

A. *Total Productive Maintenance (TPM)*

TPM is a maintenance-based tool for equipment and machinery that aims to enhance equipment effectiveness by reducing failures and accidents [2]. The TPM application involves verifying whether an organization has achieved the plan and goals established in the initial stage of the project. To measure the achieved objectives, indicators such as MTBF, MTTR, and OEE are used [3]. Additionally, before implementing TPM, it is crucial to determine the main causes of machine stoppages in the production process to be analyzed, which can be done through a Pareto Diagram. A study identified that 80% of the reasons were due to machinery failure, external failure, induced interruption, and interruption due to quality issues [4].

In the improvement project, the results of applying TPM were positive due to corrective and preventive maintenance. This led to a 23% reduction in stoppages due to failures, resulting in an increase in production capacity [5].

To achieve positive results as mentioned above, it is important to consider the following recommendations. Firstly, it is necessary to involve all levels of the company, from top management to employees directly involved in the process to be improved [6]. This allows for the creation of commitment and the setting of team objectives to ensure the proper use of techniques. Another crucial point is to incorporate the opinions and needs of users to address the malfunctioning process within the organization [7]. A study applied a series of tools that allowed them to gather customer opinions, resulting in a 37% reduction in non-conforming orders and a customer loyalty rate of 60.81% [8].

B. Lean Manufacturing

Lean Manufacturing is a management model with various approaches and tools that has achieved significant success and positive impact in various industries in terms of productivity, costs, and quality [9]. However, it is essential to identify which technique to apply based on the aspect targeted for improvement and the type of organization [10]. Studies identifies that VSM and standardized work as the most impactful tools [11].

Standardized work has yielded favorable results in both service and goods production industries. Reducing variability in a service process through standardization led to an approximately 50% decrease in the average activity time [12]. Other research also shows that standardizing a manufacturing process through manuals and reviewing tasks performed by operators reduces manufacturing time and the quantity of defective products [13].

The use of Lean tools has an indirect impact on a company's service level by maximizing resources and optimizing production [14]. Studies have confirmed this relationship, where On-Time In-Full (OTIF) has increased by 44.48% due to a 27.27% reduction in cycle time [15]. These results are supported by a study that achieve a service level of 63% in a textile sector organization by increasing machine availability to 80% [16].

On the other hand, it was found that the application of Lean Manufacturing tools along with MPS helps both to work more efficiently. A study shows that the interaction between Lean and a production planning system with MRP and MPS in environments with high demand variation and found that applying both tools has a very positive impact on the effectiveness of each [17]. Creating a model based on both MRP-MPS and Lean would allow a company to save up to $6000 in a steel factory and emphasizes that the application of both concepts is important for the improvement of a company [18].

There are also difficulties in applying a model based on more than one tool, as they must work together for their application to be effective. For example, the creation of an MPS system requires a standardized work system for its proper functioning, which can be difficult to implement if operators are not well-trained [19]. It is also important to control different KPIs when implementing these tools to ensure that they are being used correctly, requiring the hiring of a specialized team for this field [20].

III. Contribution

A. Fundament

Small and medium-sized companies in the food sector must seek continuous improvement and maintain a high level of service. Firstly, the food industry is subject to strict regulations and quality standards, demanding a constant commitment to excellence to ensure consumer safety and satisfaction. Moreover, in an increasingly competitive market, continuous improvement allows for process optimization, cost reduction, and increased operational efficiency—crucial factors for the economic viability of smaller enterprises. A high level of service not only fosters customer loyalty but also builds a positive reputation that can be decisive for long-term success and differentiation in the food industry.

This led to the development of a value proposition based on a literature review, aiming to identify models, tools, and methodologies to enhance the level of service. As a result of this search and based on the identified problem, Lean Manufacturing and Total Productive Maintenance (TPM) were determined as the proposed tools to implement in the current study.

B. Proposed Model

The proposed model is based on standardized work and TPM to increase the level of service in a food processing plant. It consists of three components: analysis of the current situation, implementation of tools, and validation of the model.

This model was defined based on the issue of low service level caused by the inefficiency of the packaging area. Starting from this improvement opportunity identified through observations within the plant, literature sources were consulted to understand what has been applied in other studies and the impacts obtained.

C. Model Components

Component 1: Problem analysis

For the development of the first component, an analysis of the company's situation was conducted to identify improvement opportunities and the root causes of these issues. To achieve this, a visit to the production plant was carried out to discover errors in the production process and define the problem that needed to be addressed. Subsequently, a problem tree was developed to visualize the various causes of the low level of service in the company. Additionally, a Pareto analysis was performed to identify the causes with the greatest impact on this indicator, allowing for a more in-depth investigation to pinpoint the root causes. Through this analysis, a low efficiency in the packaging area was identified.

Component 2: Implementation

One of the root causes of low efficiency is the unplanned stops in the packaging machine, which will be addressed through the implementation of TPM. Prior to applying the tool, a current situation analysis was conducted to determine the

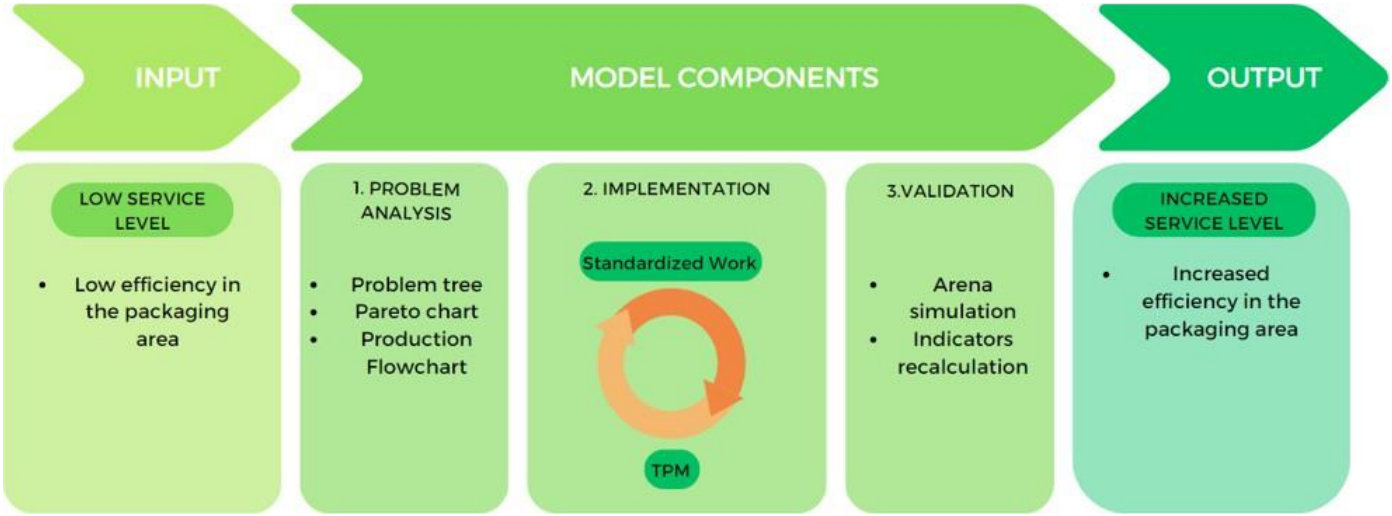

Fig. 1 Proposed model

current equipment utilization. The Overall Equipment Effectiveness (OEE) indicator was used for this purpose, measuring the comprehensive utilization of industrial machinery.

For the calculation, the available production line times and the distribution of the total calendar time, including both planned and unplanned stops, were determined. It was identified that the machine experiences approximately 39 failures per month with 26 hours dedicated to unplanned maintenance, precisely addressing the presented faults. This led to a Mean Time Between Failures (MTBF) of 2.33 hours/failure and a Mean Time To Repair (MTTR) of 0.69 hours/failure.

To meet market demand, it was established that the number of stops per month should be reduced to 30, and unplanned stop hours to 16.5. This would result in an MTBF of 3.03 hours/failure, an MTTR of 0.43 hours/failure, and an OEE of 85%. To achieve this, collaborative efforts with the machine operators are required to identify why the packaging machine is experiencing faults. An instruction manual should be created to guide them on how to correct these faults autonomously and in the shortest possible time. Additionally, training sessions should be conducted to present this document and put it into practice during a production shift.

During the plant visit, it was identified that the main cause of faults is the poor calibration of the filling scale within the packaging machine. Whenever operators detect that it is not functioning correctly, they pause the packaging operation to calibrate it properly. It is also known that operators lack sufficient knowledge and confidence to calibrate the scale, hence they seek support from maintenance personnel, resulting in a high unplanned stop time when calibration does not require it.

After identifying the root cause of the machine failures, a multifunctional team was created made up of the maintenance, operations, efficiency and human resources areas to design a training plan for the operators.

The training program is divided into four sessions designed to cover key aspects of TPM, starting with an introduction to the principles of TPM and analysis in the production process. This session will provide participants a solid understanding of the importance of TPM and how to identify and classify specific losses related to filling machine and scale calibration.

The second session focuses on autonomous maintenance, where participants will learn cleaning, inspection and lubrication procedures for the filling machine and scale. Practical exercises will be conducted to familiarize participants with these tasks and ensure their ability to perform them effectively. This session will be led by the company's maintenance team.

The third session, also led by maintenance, addresses planned maintenance and scale calibration. Here, participants will develop a specific preventive maintenance plan for the filling machine and learn techniques and procedures to properly calibrate the scales. Practical exercises will be conducted to ensure understanding and the ability to apply this knowledge.

Finally, the last session will focus on continuous improvement and TPM project management. Participants will learn about the continuous improvement process within the TPM framework, as well as tools and techniques for problem solving and decision making. Group exercises will be conducted to identify specific improvement opportunities and develop action plans to address them.

Implementing new practices in the production area is challenging so it is key to cover the following aspects during the sessions. First, some employees may not be fully engaged in the training process, which can affect the effectiveness of the sessions. It is crucial to clearly communicate the importance of the training and how it will benefit both the employees and the company. This aspect is covered in the first session of the program.

On the other hand, putting theory into practice is the key to confirm that the employees have understood the concepts. Both sessions 2, 3 and 4 have a practical approach that includes simulation exercises and case studies. Finally, to guarantee positive results, it's necessary to establish a follow-up plan that includes weekly meetings to review progress and provide feedback. In addition, recognizing and rewarding individual and team achievements can help maintain motivation and long-term commitment.

Moving to the boxing area, a lack of standardized processes was identified, warranting the use of the Standardized Work tool. Its implementation is proposed for the boxing process, which involves placing product doypacks into their respective boxes. This activity is entirely manual; therefore, the human factor was considered for time measurement and activity documentation. The analysis classified activities into VA (Value-Adding), NVA (Non-Value-Adding), and NVAN (Non-Value-Adding but Necessary).

To achieve the expected outcome, the time for some activities must be reduced. A detailed analysis of the current procedure is proposed to determine whether any activity or movement can be eliminated. Based on this, instructional guides for operators should be developed, visually placed in the boxing area for constant reference, and operators should receive training before implementation.

After a time study in the plant, it was determined that the times for activity 3 can be reduced by using a tray to collect the respective doypacks for a box simultaneously instead of doing it one by one. Additionally, the company did not have a standardized verification process for boxing conditions, so each operator is performing the activity at their discretion. It is proposed to establish the steps for verification and reduce the time for the activity.

Component 3: Validation

To validate the improvement proposals, a simulation will be conducted to measure the results and the impact that implementing this proposal would have. For this purpose, the Arena software will be utilized, which allows the simulation of the entire production process for these products. The validation stage will be presented in more detail in Chapter IV.

D. Indicators

The following indicators will be used throughout the investigation to determine if the proposed model yields favorable results. This will be done by comparing the situation before and after the implementation of the improvement.

1) Service level: Indicates the probability of meeting product demand without depleting inventory and within the agreed-upon time.

Service level = (Orders delivered in good conditions) / (Delivered orders)

2) Overall Equipment Effectiveness: Identifies the percentage of planned production time that is truly productive

OEE=Availability × Performance × Quality

= ((Run time) / (Planned production time)) × ((Real production) / (Planned production)) × ((Number of good products) / (Total products))

3) Time between failures:

MTBF = (Net production time) / (Number of failures)

4) Mean time to repair:

MTTR = (Total maintenance time) / (Number of repairs)

5) Cycle time: Indicates the amount of time it takes to complete a specific task from start to finish

Cycle time = (Net production time) / (Number of produced units)

IV. VALIDATION

To validate the proposed model, a simulation was done in Arena, which was used to prove its effect in the company.

A. Initial Diagnosis

As of today, the SME has a service level of 83%, which is considered as a low performance when comparing to similar food producing companies. This is a result of low efficiency in

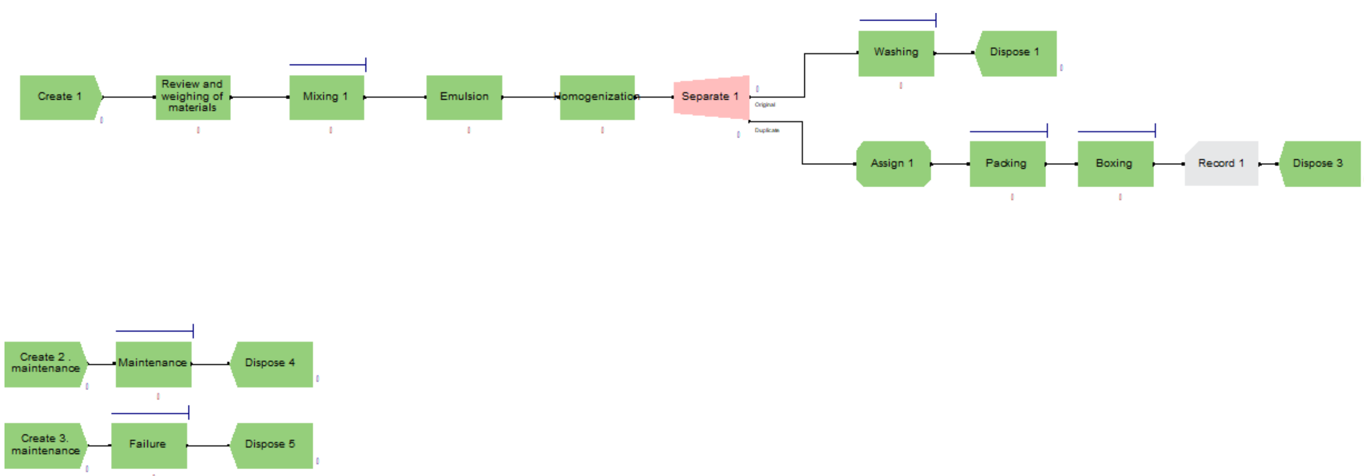

Fig. 2 Model used for the simulation in Arena

the packing zone and is caused by an inadequate working method and a large amount of machine interruptions.

B. Validation Design and Application

For the validation, it was decided that a simulation was going to be used as the method, as there were limitations preventing a pilot test in the company. Arena software was selected for its simulation capabilities. The validation methodology involves defining production process activities, determining their durations, specifying indicators for measurement, and creating simulation models for the current and proposed situations.

The development of the validation methodology includes defining production activities and their durations. Scheduled maintenance and spontaneous failures during production are considered, incorporating data provided by the company. The simulation model is constructed using two 12-doypack boxes as simulation units due to software limitations. The main branch represents the production process, while secondary branches depict scheduled maintenance and spontaneous failures. The simulation runs two consecutive shifts (16 hours per day) to better represent plant production and a Record module counts the produced boxes at the end.

C. Results

Before running the simulation, the expectations for the main indicators were calculated to know what to expect from the simulation and better compare the results.

TABLE I
CURRENT SITUATION VS EXPECTATIONS

Indicators	Current situation	Expectation
Service Level	83%	95%
OEE	58%	85%
MTBF	2.33 hrs	3.03 hrs
MTTR	0.69 hrs	0.43 hrs
Cycle Time	5.8 min	4.08 min

After that, the simulation of the current situation and the simulation of the improved situation were run 200 times for each scenario to ensure reliable results, which are presented in the next table.

TABLE II
CURRENT SITUATION VS IMPROVED SITUATION

Indicators	Current situation	Simulation results
Service Level	83%	94.2%
OEE	58%	77%
MTBF	2.33 hrs	2.76 hrs
MTTR	0.69 hrs	0.5 hrs
Cycle Time	5.8 min	4.83 min

D. *Analysis*

The implementation of TPM (Total Productive Maintenance) and standardized work in the studied company represented an ambitious approach to improving the efficiency of the production process and, consequently, the service level.

One of the most notable achievements of the project was the significant improvement in plant efficiency indicators. The project surpassed literature reference values, demonstrating a positive impact from the implementation of TPM and standardized work.

Despite these notable advances, the initially set objectives were not fully achieved. An evident example is the achieved service level, which reached 94.2% instead of the targeted 95%. It is crucial to highlight that, despite falling short of the initial goals, the results remain significant and promising, which suggests substantial progress in terms of efficiency and service level compared to other studies, indicating the project's potential for further improvement, and affirming the robustness and value of the proposals in the food industry context.

The validation of results was meticulously executed using the Arena simulator, given the impracticality of implementing improvement proposals directly into the plant processes. While simulation provides valuable insights, it is imperative to acknowledge its inherent limitations in replicating the intricacies of a real-world environment. The accuracy of simulation results hinges on the precision of input data and assumptions embedded in the model.

In this specific case, average times from the last year were utilized due to the company's constraints regarding the availability of historical data. Although these data were rigorously validated with the production manager for precision and realism, it is essential to highlight the potential for inaccuracy in the simulation results. The dynamic nature of production processes and evolving external factors may introduce variations that the simulation model might not fully capture. Therefore, while the obtained results remain valid within the specified parameters, implementing plant improvements should be approached with caution, and a pilot test is strongly recommended to validate and fine-tune the proposed enhancements in a real-world setting.

An analysis of the economic flow of the project implementation was carried out. To do this, only the impact it would have on costs and revenues was considered, as it is necessary to analyze how much benefit would be obtained by implementing the improvement proposal. A 5-year horizon was considered for the implementation, and the results are presented below. For these calculations, a Cost of Capital (COK) of 20.41% was considered.

Year	0	1	2	3	4	5
Investment	-S/ 20,250.00					
Benefit		S/ 18,960.00	S/ 18,960.00	S/ 18,960.00	S/ 18,960.00	S/ 18,960.00
Costs	-S/ 2,700.00	-S/ 2,500.00	-S/ 2,500.00	-S/ 2,500.00	-S/ 2,500.00	-S/ 2,500.00
Net Economic Cash Flow	-S/ 22,950.00	S/ 16,460.00	S/ 16,460.00	S/ 16,460.00	S/ 16,460.00	S/ 16,460.00
Discounted Economic Cash Flow	-S/ 22,950.00	S/ 13,669.68	S/ 11,352.37	S/ 9,427.90	S/ 7,829.67	S/ 6,502.37
Cumulative Discounted Economic Flow	-S/ 22,950.00	-S/ 9,280.32	S/ 2,072.05	S/ 11,499.95	S/ 19,329.63	S/ 25,832.00

Fig. 3 Economic analysis

Additionally, the calculation of the following economic indicators was performed: Net Present Value (NPV), Internal Rate of Return (IRR), Cost/Benefit ratio (C/B), and Payback Period (PP).

TABLE III
ECONOMIC INDICATORS

Indicators	Result
NPV	S/ 7,925.24
IRR	38%
C/B	S/ 1.35

PP	1.82 years

The project's financial evaluation is shown in the previous table, revealing key metrics that offer valuable insights for decision-making. The Net Present Value (NPV) of S/ 7,925.24 indicates a positive financial outcome, considering the present value of future cash flows discounted at the rate of return. With an Internal Rate of Return (IRR) at a robust 38%, the project demonstrates its capacity to generate substantial returns, surpassing expectations. The Cost/Benefit Ratio (C/B) at S/ 1.35 underscores the favorable relationship between costs and benefits, serving as a crucial measure of economic efficiency. Despite a Payback Period (PP) exceeding a year at 1.82 years, the relatively short duration suggests a swift recovery of the initial investment through the project's generated cash flows. In conclusion, these indicators collectively affirm the project's economic viability, indicating positive financial prospects and the potential for long-term gains and strategic success.

A sensitivity analysis was also conducted to test what would happen if the demand were to vary in 10%. It was made using the software @RISK and both the NPV and IRR were tested. The results are presented in the next table.

TABLE IV
SENSITIVITY ANALYSIS RESULTS

Indicators	Minimum value	Maximum value
NPV	S/ 4,496.13	S/ 11,326.98
IRR	30.45%	45.2%

These results indicate that, even in the worst-case scenario, the proposed improvements to the production process would have a positive impact and they should be applied to improve the company’s operations.

This analysis serves as a crucial tool in substantiating the economic viability of the project, aiding in the decision-making process regarding the potential benefits of the investment for the company. Apart from affirming the project's positive impact on productivity, it distinctly illustrates a positive trajectory for cash flow enhancement in the following years.

V. Conclusions

By using Lean Manufacturing and Total Productive Maintenance it is possible to improve the OTIF of a SME in the food sector from 83% to 94.2%. It is also possible to improve the service level from 83% to 94.2%, which is a consequence of increasing the MTBF (Mean Time Between Failures) by 18% and reducing the MTTR (Mean Time to Repair) by 27%.

To achieve these results, everyone in the company must show a high level of commitment so that the production process can be changed, and the new upgrades are applied efficiently. For that, the ones in charge should plan accordingly and establish objectives so that everyone knows what to do to improve their work.

The achieved metrics of MTBF and MTTR highlight the tangible improvements in the reliability and efficiency of the production process. These enhancements contribute to a more robust manufacturing environment, indicative of the positive impact of Lean Manufacturing and TPM.

Looking forward, it is recommended that future investigations employ multiple validation methods, such as simulation and pilot testing, to deepen the understanding of the proposed model's efficacy. This multifaceted approach would not only bolster the validation process but also provide richer data for informed decision-making before contemplating full-scale implementation.

Beyond the specific company under study, the implications of this research extend to the broader food sector and analogous industries grappling with similar challenges. The successful application of Lean Manufacturing and TPM serves as a valuable case study, offering a roadmap for addressing common issues related to productivity, efficiency, and service levels in the dynamic and competitive landscape of the food industry. In conclusion, the collaborative implementation of Lean Manufacturing and Total Productive Maintenance has proven effective in reshaping the operational dynamics of a company within the competitive food sector, affirming the potential benefits of these methodologies for further adaptation in comparable industrial contexts.

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