

# **Improvement Proposal for Supply Chain Management in Peru's Sausage Industry Using Lean Logistics and Kraljic Matrix with Structural Equations**

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## **Abstract**

This study addresses procurement challenges in Peru's sausage industry, particularly the dependence on foreign pork suppliers and rising international prices that increase production costs. To mitigate these issues, an improvement model is proposed, integrating Lean Logistics for process standardization and the Kraljic Matrix for supplier evaluation and selection. Structural equation modeling was applied to validate the relationships between these tools and firms' performance. The results indicate significant correlations between Lean BPM and non-financial performance (0.61), and between the Kraljic Matrix and financial performance (0.46). The implementation of the model resulted in a 27% reduction in raw material purchasing costs and a 60% improvement in operational efficiency. These findings suggest the model's potential contribution to enhance supply chain resilience and competitiveness, while acknowledging that correlation does not imply direct causality and that generalizability may be limited by the sample size.

## **Keywords**

Sausage Industry, Lean Logistics, BPM, Kraljic Matrix, Structural Equations.

## **1. Introduction**

In Peru, sausages represent one of the main processed foods consumed by households. Nevertheless, in recent years the industry has experienced significant sales fluctuations. According to INEI (2022), from 2017 to the first quarter of 2021, there were inexplicable variations in sales, where it is evident that in 2018 there are 73,575 tons sold of sausages (Hot dog, jamonada, ham and chorizo) but the following year (2019) there is a total sale of 60,025 tons. This irregularity in sales, adding COVID 19, directly affected the sector's production, creating an increase in operating costs for sausage companies.

Sofia Villanueva, regional supervisor of Plaza Vea with more than 7 years working in the company and with experience in the sausage sector, explained that one of the main problems that the sausage industry has is in the supply of raw material purchases (pork); This is due to the fact that some companies in the sector are dependent on foreign suppliers, because very few domestic suppliers have quality certificates; however, as pork prices increase worldwide, this directly affects production costs. In addition, there is not enough production in the domestic market to satisfy the domestic demand of the companies. This generated an approximate 6.67% increase in costs in the last quarter of the year in some companies in the sector (Sigma Alimentos 2023).

A causality tree was developed to identify the main problem, as well as its associated causes and effects. This graphic tool makes it possible to visualize in a clear and structured manner the relationships between the various factors that influence the central problem.

This research seeks to optimize logistics operations in the sausage industry. The implementation of Lean Logistics helps to eliminate waste and improve efficiency. By integrating structural equation modeling, relationships between logistics variables can be analyzed and performance improvements can be predicted and then optimized. This study not only provides theoretical knowledge, but also offers practical tools to improve the quality of suppliers of Peruvian companies, as well as the economic development of the sector.

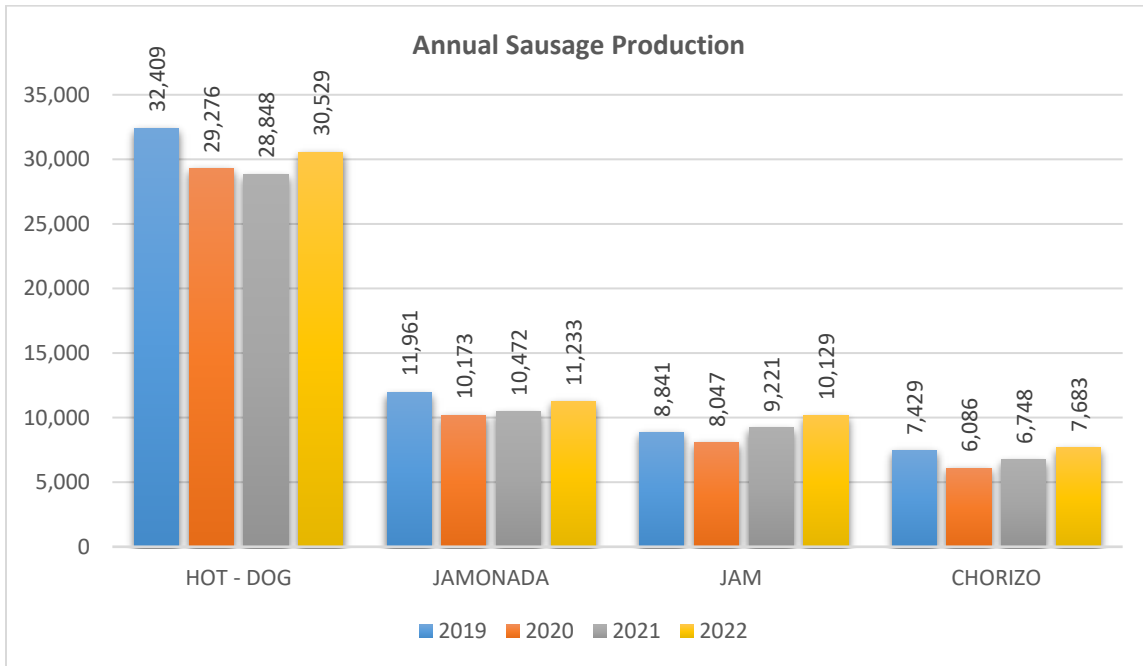


Figure 1. Annual Sausage Production

The data presented in Figure 1 and Table 1 clearly demonstrate the significant production of sausages in the country. The proposed research not only addresses a critical market need, but also offers innovative solutions to improve efficiency and reduce costs in the supply chain of the sausage industry in Lima.

Table 1. Production and processing of sausage products in tons

Sausages and smoked meats	2016	2017	2018	2019	2020	2021	2022 P/
Hot dog - sausages	27,297	31,159	41,746	32,409	29,276	28,848	30,529
Chorizos	6,357	6,968	7,999	7,429	6,086	6,748	7,683
Jamonada	11,690	12,680	15,361	11,961	10,173	10,472	11,233
Jam	7,045	7,192	9,216	8,841	8,047	9,221	10,129
Pate	567	564	377	562	571	588	557
Smoked meats	1,826	1,714	1,827	1,998	1,691	1,983	1,842

## **1.1 Objectives**

The general objective of the study is to propose an improvement model for supply chain management in the sausage industry in Lima, Peru, by integrating Lean Logistics and the Kraljic Matrix through the application of structural equations. To achieve this, the main factors and critical variables affecting the supply chain will be investigated and identified, the feasibility of developing a mathematical model to detect production issues will be assessed, and the impact of simulating Lean BPM tools and the Kraljic Matrix on production efficiency and cost reduction will be analyzed.

## **2. Literature Review**

Kovac and Rivera (2022) state that working models using BPM and the Kraljic matrix are not suitable for agribusiness companies in Latin America. Therefore, they have chosen to implement the mentioned tools in one of the companies in the sector. In their simulation, they have shown that they can optimize resources by up to 60% and reduce processing times. Dobrosavljević (2021), states that BPM in organizations in the garment industry can be considered as a crucial practice for establishing a stable and progressive business because it contributes to the overall improvement of the organization's operations with this tool. In addition, the influential elements defined by the tool are treated as variables in a structural equation model of SPSS and AMOS to explore the hypothesized impacts of BPM. Coronel et al. (2022) state that, to improve the competitiveness of textile companies, it is essential to implement Lean Logistics, focused on optimizing delivery times and reducing unnecessary expenses. After the simulation, a 40.55% reduction in purchasing costs was achieved, in addition to significant improvements in delivery times, providing a lasting solution for a better evaluation of the processes. Díaz-Reza et al. (2024) analyzed the maquiladora industry in Mexico using structural equation modeling (SEM) to evaluate the impact of Lean practices on social sustainability. Their study, based on survey data from more than 400 respondents, confirmed that Lean methodologies can drive measurable improvements beyond operational performance, addressing broader organizational challenges in the long term.

## **3. Methods**

The research is of an explanatory-correlational nature. According to Hernández (2014), it falls under the explanatory category due to its aim to understand why and how two or more variables are related. On the other hand, it is also considered correlational as it seeks to establish the degree of relationship between the identified variables. The study population was selected from 33 companies in the sausage sector, identified in the Perú Top Publications (2022) database. Additionally, the analysis was conducted using a structural equation model through AMOS software version 26. A macro design of the solution was also applied, which involved four phases: diagnosis of the initial situation, solution design, solution development, and solution validation. Each of these phases was evaluated with specific indicators to measure the progress of the study design.

For the study hypothesis, the development of the conceptual model was considered, along with the proposal by Avalos et al. (2018); therefore, the following hypotheses are proposed:

H1: Lean Logistics with BPM has a positive impact on financial performance.

H2: Lean Logistics with the Kraljic Matrix has a positive impact on financial performance.

H3: Lean Logistics with the Kraljic Matrix has a positive impact on non-financial performance.

H4: Lean Logistics with BPM has a positive impact on non-financial performance.

H5: An inference is made from hypotheses 1 and 4 regarding the relationship between Lean Logistics and Business Performance

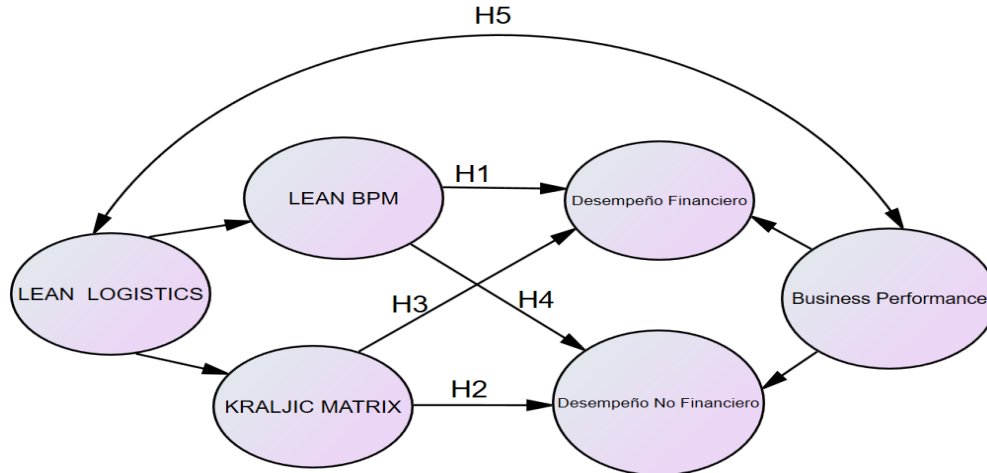


Figure 2. Conceptual model of Lean Logistics and performance

The research aims to analyze the relationships between the constructs shown in Figure 2. Lean Logistics is an engineering tool based on Lean Management, designed to improve the logistics and supply chain areas by incorporating Lean ideas and an agile approach (Wronka 2016). BPM and the Kraljic Matrix are part of the Lean Logistics toolkit; BPM enables the automation and optimization of processes within the organization, while the Kraljic Matrix focuses on enhancing the functions of the procurement area (Kovac et al. 2022). On the other hand, Business Performance encompasses two aspects financial and non-financial performance which provide insight into the impact on the organization (Avalos 2018). Therefore, we believe there may be a relationship between Lean Logistics and the organization's Business Performance, as well as between their variables, as explained in the hypotheses (Avalos 2018).

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#### 4. Data Collection

The sample was calculated using a finite population, where the population is known, and with the following formula:

$$n = \frac{NZ^2pq}{e^2(N-1) + Z^2pq}$$

Figure 3. Equation to calculate the sample

The sample elements are as follows: N is the population size, Z is the confidence level, p is the probability of success, q is the probability of failure, and e is the margin of error. For the study, the following values were considered: N=33, Z=1.96 (95%), p = 0.5, q = 0.5, and e = 0.08. Applying the data to the formula, a sample size of 28 companies was obtained (Vargas et al. 2017). The type of sampling used was non-probability convenience sampling, which allows us to arbitrarily select the type of participants to be included in the sample (Hernández 2021). As a result, the final sample consisted of 15 companies, using the criteria of medium-sized companies with annual revenues between 1,700 and 2,300 UITs, and large companies with annual revenues exceeding 2,300 UITs (MEF 2024). This yielded a total of 222 samples for the survey, where the minimum value required to correctly apply the structural equation model is 200

samples, given that the model is not complex (Hair et al. 2014). The unit of analysis for the research is comprised of operators, supervisors, and managers from sausage companies in Lima, as well as professors from the Industrial Engineering program at the University of Lima, participating as experts (Table 2).

For this research, a questionnaire was used, which meets the validity of a measurement instrument due to its ability to measure the variables for which it was designed (Villavicencio et al. 2016). This questionnaire consists of 36 questions, covering 3 questions for each variable shown in Figure 3. The variables of financial performance and non-financial performance pertain to supply chain and logistics performance indicators (Zuluaga et al. 2014); whereas the variables of Lean BPM and the Kraljic Matrix are factors of alternative solutions from the tools (Kovac et al. 2022).

## 5. Results and Discussion

### 5.1 Numerical Results

After data collection and establishment of Amos software version 26 and revenue data, the results are shown in Figure 4 with the final validation model, which shows the relationship of the Lean Logistics variables with financial and non-financial performances. To build a mathematical model in IBM AMOS using structural equations, it is essential to follow a series of methodical steps. First, the research problem must be defined, clearly identifying the variables involved, both observed and latent. Subsequently, a theoretical model is developed based on a review of the existing literature, establishing the hypothetical relationships between the variables. The data is then loaded into IBM AMOS via a .sav or .csv file format. Once the data are available, the graphical interface is used to build the structural model, where latent variables are represented as ovals and observed variables as rectangles. Relationships between variables are indicated by arrows showing the direction of influence, and values are assigned to the relevant covariances (Byrne, 2016). Subsequently, the model is specified using the "Analyze" menu, selecting the "Estimate" option to calculate the model parameters. It is crucial to evaluate the model fit using goodness-of-fit indices, such as Chi-square, CFI and RMSEA, and to adjust if the results are not satisfactory. This systematic approach ensures the validity and reliability of the proposed structural model (Byrne 2016).

Table 2. Evaluation indices and variables used in the structural equation model (adapted from Mazo et al., 2014)

Evaluation Indices	Variable	Code	Evaluation Indices	Variable	Code
Lean BPM	Performance in purchase or order generation time	L1	Financial Performance	Raw materials purchase costs	DP1
	Process standardization	L2		Investment in ICT in the supply chain	DP2
	Workload	L3		Supply chain administration costs	DP3
Kraljic Matrix	Supplier concentration	K1	Non-financial Performance	Supplier delivery time per order	DN1
	Number of contracts between suppliers	K2		% of complaints about acquired products and perfect deliveries	DN2
	Number of rejected orders	K3		Number of purchases from certified suppliers	DN3

For the reliability of the questionnaire results, Cronbach's alpha was used to see if the results are reliable. In addition, to determine the level of validation, the coefficient value must be greater than 0.7 (Yüksel 2008).

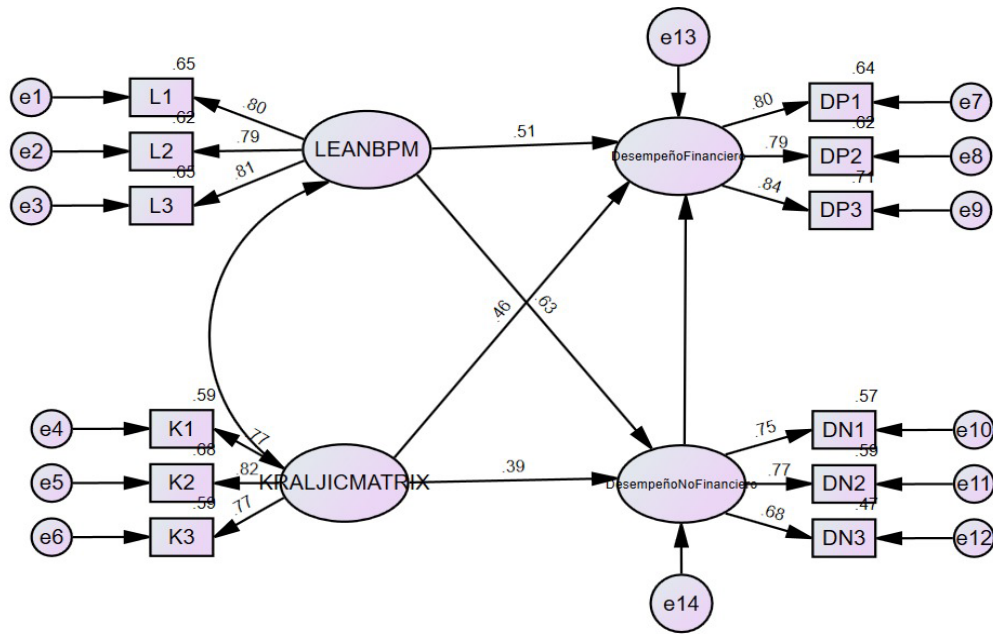


Figure 4. Validated structural equation model

From the final mathematical model, it is concluded that the values of the hypothesis paths are positive, meaning that these variables present a significant relationship and support the hypotheses mentioned above. In addition, a correlation of 0.46 indicates a moderate relationship between the Kraljic matrix and financial performance. However, the correlation is not strong, which implies that there are other factors that also influence non-financial performance. On the other hand, a correlation of 0.63 indicates a stronger positive relationship between Lean BPM (Business Process Management) and non-financial performance. This suggests that organizations implementing Lean practices tend to report higher efficiency and effectiveness in their processes, which is associated with improvements in cost reduction and revenue (adapted from Avalos 2018). However, it is important to note that these findings indicate correlation rather than direct causality, as other factors may also influence financial outcomes (Table 3).

Table 3. Summary of correlation coefficients for tested hypotheses

Hypothesis	Route Relation	Route Coefficient
H1	Lean BPM	0.51
	Financial Performance	
H2	Kraljic Matrix	0.46
	Financial Performance	
H3	Kraljic Matrix	0.39
	Non-financial Performance	
H4	Lean BPM	0.63
	Non-financial Performance	

For the evaluation of the quality of the mathematical model, various statistical indicators are used in AMOS to guarantee the validity and reliability of the model (Table 4). These indicators help to determine how well the

theoretical model fits the empirical data. Certain indicators, such as the GFI (Goodness of Fit Index) to the IFI (Incremental Fit Index), must have values greater than 0.90 (Ruíz et al 2010) to consider a mathematical model correctly validated. On the other hand, the RMSEA (Root Mean Square Error of Approximation) has a different limit than the others. This limit must not be exceeded with a maximum acceptable value of 0.08, which explains the amount of variance not explained by the model per degree of freedom (Herrero 2010).

Table 4. Statistical indicators for model validation

Statical Indicator	Values	Accepted Values
Chi-square ratio/degrees of freedom	2.77	<3
GFI	0.908	>0.90
AGFI	0.89	>0.90
CFI	0.957	>0.90
TLI	0.941	>0.90
IFI	0.958	>0.90
RMSEA	0.079	<0.08

## 5.2 Graphical Results

With the final validation model already completed and the relationship between the variables demonstrated (Avalos 2018), an exhaustive research and search for articles similar to ours that have been implemented and achieved a result was carried out in order to estimate and understand what the benefits and impact of the tools are; for this, Figure 5 will show the process map of the purchasing area of the industries to graph where exactly the participation of the tools within the supply chain of the industries is desired. From the process map, it is desired to implement, specifically, the “Supplier Evaluation” process, where it is sought to improve with the Kraljic matrix, a better management of the choice of suppliers and improve the supply chain (Ye 2021), and also with the BPM, seek the standardization of the processes that allow better allocation of economic resources (Granda 2022).

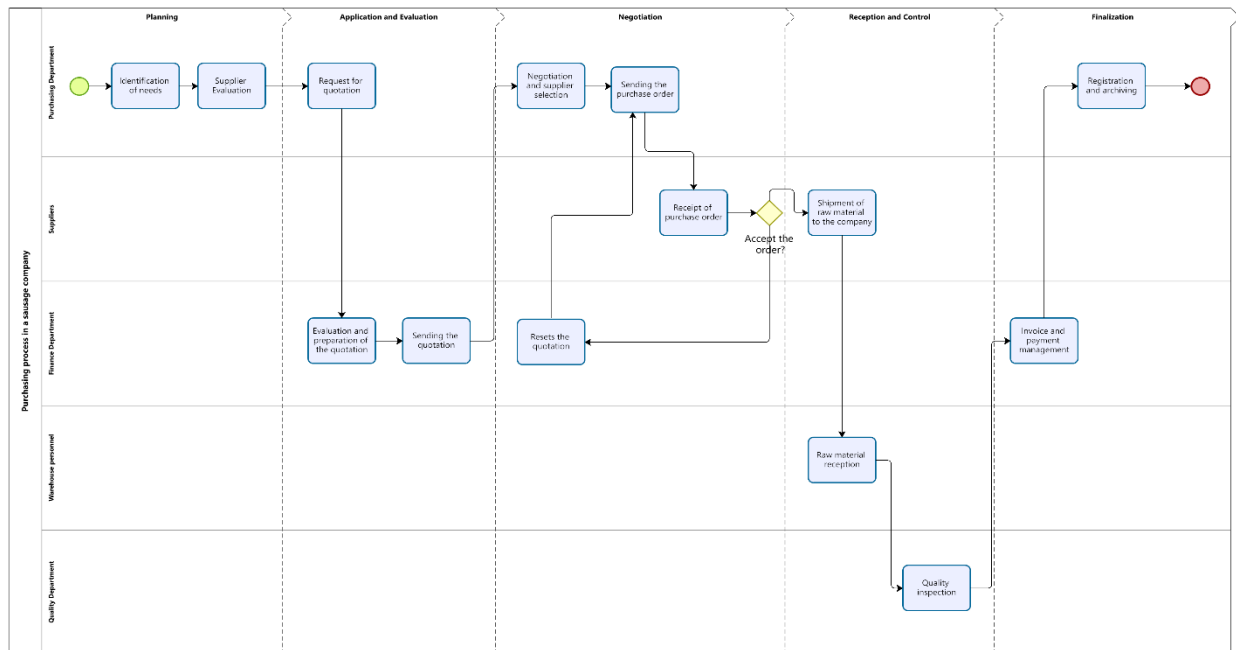


Figure 5. BPMN process map of procurement in the sausage industry, highlighting supplier evaluation.

### **5.3 Proposed Improvements**

After graphing the process that is desired to be modified and improved; In addition, to demonstrate that the tools have a relationship with the financial and non-financial performance of companies, the article by Kovac et al. (2022) entitled “Application of the BPM-Kraljic model to improve supply management in an agro-industrial company” was used. This study focused on improving the supply management of an agro-industrial company by implementing the same tools: BPM and the Kraljic matrix. The results showed a cost reduction of approximately 27% in the purchase of materials and a significant improvement in the standardization of internal processes, achieving a 60% increase in operational efficiency by reducing unnecessary times in the process. Due to the similarity in the use of the tools and the variables considered, the data obtained from this study will be used as a reference for our research.

### **5.4 Validation**

In our research, we focused on improving procurement management in sausage industries by implementing Lean Logistics, with the aim of reducing procurement costs. On the other hand, Dobrosavljević (2021) used the Business Process Management (BPM) tool to explore the relationship between staff competencies in the apparel industry. Using structural equations in AMOS software, Dobrosavljević analyzed a sample of 508 employees and found a significant value of 0.69, showing that BPM can be effective in improving both staff competencies and process management in this industry. Although our study and Dobrosavljević's study share the premise of optimizing management through specific tools and a similar correlation result of 0.69 for Dobrosavljević and 0.63 for the present study, the differences in the results of the structural equation models can be attributed to the larger sample size used in Dobrosavljević's study. This methodological difference underlines the importance of sample size in the validity and generalizability of findings in research of this type. Danylenko (2021) used in his research that focuses on the optimization of logistics processes in the food supply chain with lean tools, where he managed to reduce unnecessary expenses of about \$72,277.78 dollars, which represent approximately 15% of the costs of the supply area, where they differ in the approach to the supply chain, where they cover the production, purchasing and logistics part, a much broader and more complete approach that affects the company's production much more. For Coronel et al. (2023), they focused their methods on using lean tools to improve order delivery with cost reduction due to purchases of defective materials, where they managed to reduce purchasing costs by 40.55%, where, mainly, they executed a logistics management model for a textile company that had many difficulties in its production and irregularities that drastically affected its costs. It can be deduced that the results of lean logistics tools can have a significant impact in reducing purchasing costs in different industries, where their impact will depend on various factors such as the type of industry, historical data of the company, focus of the tools, among others, which directly influence the results (Fallas et al. 2018).

## **6. Conclusion**

This study proposes and validates a supply chain improvement model for Peru's sausage industry by integrating Lean Logistics and the Kraljic Matrix, supported through structural equation modeling. The findings confirm significant correlations between Lean BPM and non-financial performance (0.63), and between the Kraljic Matrix and financial performance (0.46). Implementation of these tools resulted in a 27% reduction in raw material purchasing costs and a 60% increase in operational efficiency, demonstrating their practical value in enhancing procurement management and competitiveness. The main contribution of this study is the development of a replicable methodological framework that combines process standardization with strategic supplier evaluation, tailored to an industry highly dependent on imported inputs. The research was based on a sample of 15 companies in Lima's sausage sector, which provided valuable insights but also represents a limitation regarding sample size and generalizability. Future research could expand the model to other industries or regions and conduct cross-industry comparisons to test its robustness. Overall, this work advances both theory and practice in supply chain management by showing how Lean Logistics and the Kraljic Matrix can jointly strengthen resilience, efficiency, and sustainability in procurement operations.

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