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Application of Poka-Yoke and the Kraljic Matrix to Reduce the Delivery Time Index in an SME in the Coffee Sector

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Abstract

Peruvian coffee companies struggle with supply chain inefficiencies, resource waste, and quality control due to poor supplier management and ineffective error prevention. To address this, the proposed solution involves implementing the Kraljic Matrix for strategic supplier classification and the Poka-Yoke system to prevent production errors. A base model simulation using Arena software, with 7,159 replications and the 95% confidence intervals for the indicators demonstrated reliability and validated significant productivity improvements, including increased daily coffee production, reduced operational costs, and higher revenues. An economic analysis confirmed the project's financial viability with positive NPV and TIR. This initiative also benefits stakeholders through fair trade practices for farmers, improved conditions for plant workers, and promotes environmental sustainability by reducing waste and encouraging responsible resource management. The results obtained are favorable and show a great improvement compared to the initial situation of efficiency in logistics management, since the efficiency improved from 49.71% to 76.97%.

Keywords
Coffee Sector, Productivity, Delivery Time, Kraljic Matrix and Poka-Yoke.

1. Introduction (12 font)
The Peruvian coffee sector, although considered small compared to major global producers like Brazil, Vietnam, and Colombia, has high growth potential due to the quality of its coffee and the increasing demand for specialty coffees. In the global context, worldwide coffee production has seen fluctuations in prices and volumes, influenced by factors such as climate, international supply, and demand. According to the International Coffee Organization (ICO), in April 2022, the price of coffee increased by 1.8%, reaching an average of 198.37 U.S. cents per pound. Global exports of green coffee beans grew by 2.6% in March 2022, driven primarily by increases in exports from Brazil. According to Rojas-Salas and Barahona-Palomo (2020), the Peruvian coffee sector is in a stage of growing development and expansion in both the national and international markets. Coffee is one of the country's main export products, making it an important economic driver for Peru. However, the sector faces several challenges in terms of social, economic, and environmental sustainability. In line with these issues, significant problems have been identified in the Peruvian coffee sector's supply chain. Recurring issues include the scarcity of coffee supplies from providers

and the limited relationships between companies in the sector and these farmers. Additionally, there is some environmental impact from cultivating crops that are not native to the region (Diaz Vargas & Willems, 2017). In Peru, coffee is the third most economically important agricultural activity, after oil palm and sugarcane. Coffee production involves approximately 233,000 households across 16 regions of the country, representing a significant portion of the rural population dedicated to this crop. Regarding macroeconomic indicators and the sector's performance, the coffee industry contributes significantly to the country's agricultural GDP and generates employment for a large portion of the rural population. According to data from the Peruvian Ministry of Agriculture and Irrigation (MINAGRI), the main coffee-producing regions—San Martín, Junín, Cajamarca, Amazonas, and Cusco—account for 86% of the total green coffee beans produced in the country. Peruvian coffee exports have shown variations influenced by both global and local factors, and it is crucial to improve logistical efficiency to increase competitiveness in the international market.

1.1 Objectives
The objective of this research is to demonstrate that the Kraljic Matrix and Poka-Yoke will reduce the delivery time index in the coffee sector. First, Kraljic Matrix will be used to classify providers of distribution services and optimize the flow of finished products to markets. Finally, by applying Poka-Yoke principles, we aim to significantly decrease human error rates during production.

2. Literature Review
2.1 Poka-Yoke in the coffee sector
The integration of Poka-Yoke principles in the coffee sector is increasingly driven by technological advancements aimed at enhancing quality control and supply chain integrity. The core concept of Poka-Yoke, which involves preventing defects by mistake-proofing processes (Belu et al., 2015), is now being adapted through sophisticated digital tools. This is evident in the use of automated systems for quality assessment, as highlighted by Gope et al. (2024), who discuss how YOLO models can act as a form of Poka-Yoke by automatically identifying and classifying defects in green coffee beans. This technological application eliminates human error in the crucial sorting process, ensuring product uniformity. Complementing this, Rehman et al. (2025) propose a mobile application utilizing blockchain and RFID technology to improve transparency and traceability. This system effectively applies Poka-Yoke by embedding safeguards against fraud and operational mistakes throughout the supply chain, from farm to consumer, thereby ensuring that quality standards are maintained at every stage.Ultimately, this approach aims to deliver substantial economic value by improving coordination, cutting costs by up to 20%, reducing inventory carrying costs by 15-25%, and boosting crop productivity by as much as 15%.

2.2 Kraljic Matrix in the coffee sector
The strategic management of procurement is a critical concern for modern businesses, a principle underscored by several key academic works. Wagner, Padhi, and Bode (2013) highlight the core utility of the Kraljic Matrix as a foundational tool for developing differentiated purchasing strategies. This methodology, which classifies goods and supplier relationships based on their profit impact and supply risk, offers a powerful framework that can be readily applied to the coffee industry to optimize procurement. Supporting this, Gelderman and Mac Donald (2008) show that the matrix is adaptable, even in challenging environments with underdeveloped logistics infrastructure—a highly relevant point for many coffee-producing regions in Peru. This demonstrates that the Kraljic framework is not limited to ideal supply chain conditions but can be a flexible tool for navigating the unique challenges of rural, remote suppliers.

To enhance the objectivity of this approach, Montgomery, Ogden, and Boehmke (2018) introduce quantitative methods that allow for data-driven decisions within the Kraljic framework, moving beyond a purely qualitative assessment. These quantitative enhancements can be particularly beneficial for coffee producers aiming to make precise, evidence-based choices. Finally, Jaipuria, Jenamani, and Ramkumar (2016) reinforce the importance of a strategic approach to raw material procurement, a principle that is directly applicable to securing high-quality green coffee beans. Their work emphasizes that a strategic mindset is essential for managing procurement costs and navigating market volatility. While Varga, Smolnicki, Babič, and Caesarendra (2023) present findings on energy efficiency, the principles of cost-benefit analysis within their research align with the broader goal of optimizing production. In sum, these diverse sources collectively affirm that by adapting and modernizing the Kraljic Matrix, the coffee sector can implement robust procurement strategies to enhance efficiency, manage risks, and ultimately improve profitability.

2.3 Delivery time in the coffee sector

Improving delivery time in the coffee sector is a multi-faceted challenge that requires a combination of advanced manufacturing practices, automation, and predictive modeling across the supply chain. The foundational principle of this improvement lies in the adoption of effective manufacturing strategies, as Avelar-Sosa et al. (2018) demonstrate that practices like Just-In-Time (JIT) and Total Quality Management (TQM) have a direct positive impact on shortening delivery times. This is further supported by the application of technology at a granular level, with Kittichotsatsawat et al. (2023) highlighting how the deployment of automated machines, such as color sorters, in coffee production can drastically reduce cycle time by over 82% and processing time of green coffee beans by nearly 97%. This significant improvement in efficiency directly boosts responsiveness to customer demand. Moving beyond the production floor, delivery time is also influenced by upstream planning and forecasting. Rodríguez et al. (2022) illustrate this by presenting a non-destructive time series model that helps coffee growers estimate production, enabling better planning and resource allocation to ensure timely harvesting. This upstream efficiency is crucial for the entire value chain, as evidenced by Minten et al. (2019), who analyze how improvements in production and post-harvest practices in Ethiopia have led to better overall farm performance and, by extension, better delivery times. Lastly, the challenge of predicting and meeting delivery dates is addressed by Maier et al. (2022), who propose using machine learning to create realistic delivery schedules that account for real-time production capacity, thus improving both efficiency and customer satisfaction. Together, these studies emphasize that a holistic approach—from advanced manufacturing and farm-level planning to predictive analytics—is essential for optimizing delivery times and enhancing competitiveness in the global coffee market.

2.4 Poka Yoke, Kraljic Matrix and Delivery time in the coffee sector

A foundational aspect of supply chain management is the strategic classification of suppliers and the implementation of robust quality control. The Kraljic Matrix, a tool for segmenting suppliers by profit impact and supply risk, is a cornerstone of this approach. While its application has been demonstrated in sectors like Moroccan construction (Fatima Zahra et al., 2024), its principles can be directly applied to the coffee industry to improve supplier management and mitigate supply risks. This strategic lens is further supported by Gangurde and Chavan (2016), who advocate for benchmarking purchasing practices using the Kraljic approach to foster supply chain excellence. Additionally, a power and dependence perspective, as explored by Dabhilkar et al. (2016), provides crucial context for understanding and managing supplier relationships for long-term sustainability. These strategic procurement practices can be complemented by technological interventions that serve a similar purpose to Poka-Yoke, or mistake-proofing. For example, the use of fuzzy logic to create an automated temperature and moisture control system for coffee bean dryers (Syamsiana et al., 2023) acts as a preventative measure to ensure consistent quality and prevent errors. Furthermore, enhancing delivery time and overall efficiency is a key theme, as illustrated by Magableh et al. (2025), who propose integrating fuzzy logic and simulation methods to improve Jordan's coffee supply chain. This focus on efficiency and quality is also reflected in the broader push for sustainable, circular economies, as explored by De Felice et al. (2025), where technologies like IoT are used to optimize supply chains and reduce waste. Finally, the strategic use of information technology, such as agent-based architectures (Ghiassi & Spera, 2007), can support the complex, data-driven decisions needed to manage these modern, interconnected supply chains, ensuring that they are both efficient and responsive to market demands.

3. Methods

This article is a case study, which was conducted in a company belonging to the coffee sector, which allowed an analysis of the operation of companies in this industry.

The proposed model has an INPUT(input), the low levels of deliveries on time and it is expected that the OUTPUT(output) will significantly increase this indicator according to the sector indicator. In this way the proposed model is based on three phases: diagnosis of the problem, simulation and implementation of the simulation, as can be seen in Figure 1.

First, a diagnosis of the problem to be addressed was made by analyzing the current situation of the company and the processes involved in the production of coffee beans, with the following steps: a Pareto diagram to determine the times and quantify the main problems of the process, determining that the deliveries was the one that presented the greatest number of setbacks, an Ishikawa diagram to determine the causes that originate the problem and finally a problem tree that evidences the problem to be addressed and its economic impact, in addition to its reasons and root causes. In this way, it was identified that the main reasons for low level of deliveries time were poor planning of the fabric layout due to high lot change times and absence of visual tools, inefficient use of the workspace due to different physical limitations, and finally a high amount of waste due to inadequate quality control.

Once the problems and their causes were identified, an investigation was conducted to find tools that could provide engineering solutions and improve efficiency, seeking to improve the delivery time indicator. For this, the proposed model considers appropriate the integration of 2 engineering tools through a simulation, which complement each other, which are the following: Kraljic Matrix and Poka-Yoke. Finally, the level of delivery time improvement is measured once the simulation has been conducted, and a comparison is made between the current situation and the situation proposed by the model. Considering the above, Figure 1 shows the proposed model and its development.

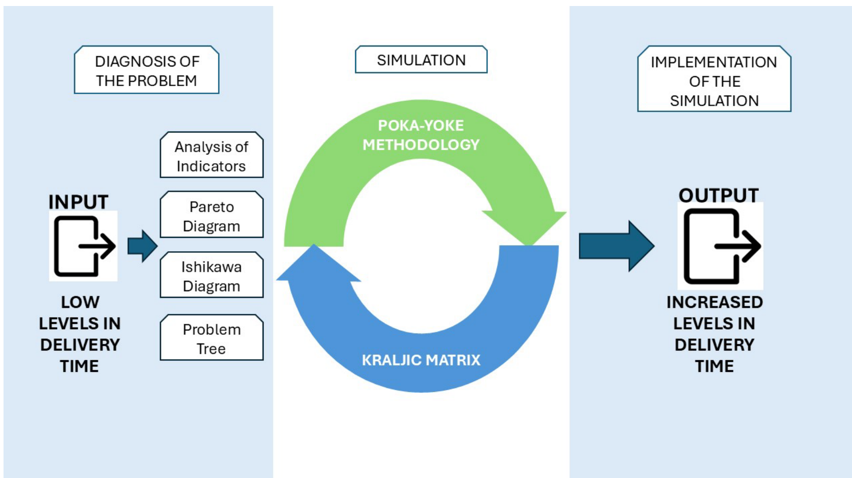


Figure 1. Proposed model

4. Data Collection

For data collection, various instruments and tools were used. The direct observations were carried out at the company's facilities, documenting times, movements, and procedures. These observations allowed a detailed and precise understanding of current processes. For this, stopwatches and cell phones were used to measure and accurately record the time of the activities.

The cameras were used to record the activities and conduct a detailed analysis. subsequent analysis of the processes. The observations were recorded in notebooks with a pencil, using a standardized observation sheet to ensure consistency in the data collection.

Additionally, structured surveys were designed for the participating employees, collecting information about logistical challenges, employees' perceptions about the efficiency of the current processes and their suggestions for improvements. These surveys were distributed and collected anonymously, and their responses were processed using statistical analysis software.

Additionally, semi-structured interviews were conducted with the purchasing managers, reception staff, and warehouse personnel. These interviews provided qualitative information about the experiences and opinions of the employees regarding the logistics processes and the areas that need improvement. The interviews were conducted in a private setting to allow for an open discussion, and were recorded and transcribed with the participants' consent for later analysis.

Internal company records were also reviewed, such as receipt reports of materials, inventory reports, and delivery time records. These documents provide crucial quantitative data for the analysis of logistical performance before and after the implementation of the improvements. These records were accessed under strict confidentiality measures, and the data were digitized and organized into a database for analysis.

The data collection procedure followed several stages. First, a detailed plan was developed, including schedules and assignment of responsibilities, detailed plan, including schedules and assignment of responsibilities. The observer and interviewer were trained to the observer and interviewer to ensure consistency and accuracy in data collection of data. During the data collection phase, the observer made visits to the warehouse and areas of reception to document the logistical processes using a standardized observation sheet. The surveys were distributed and collected anonymously. Finally, the internal records were digitized and organized into a database for analysis (Figure 2).

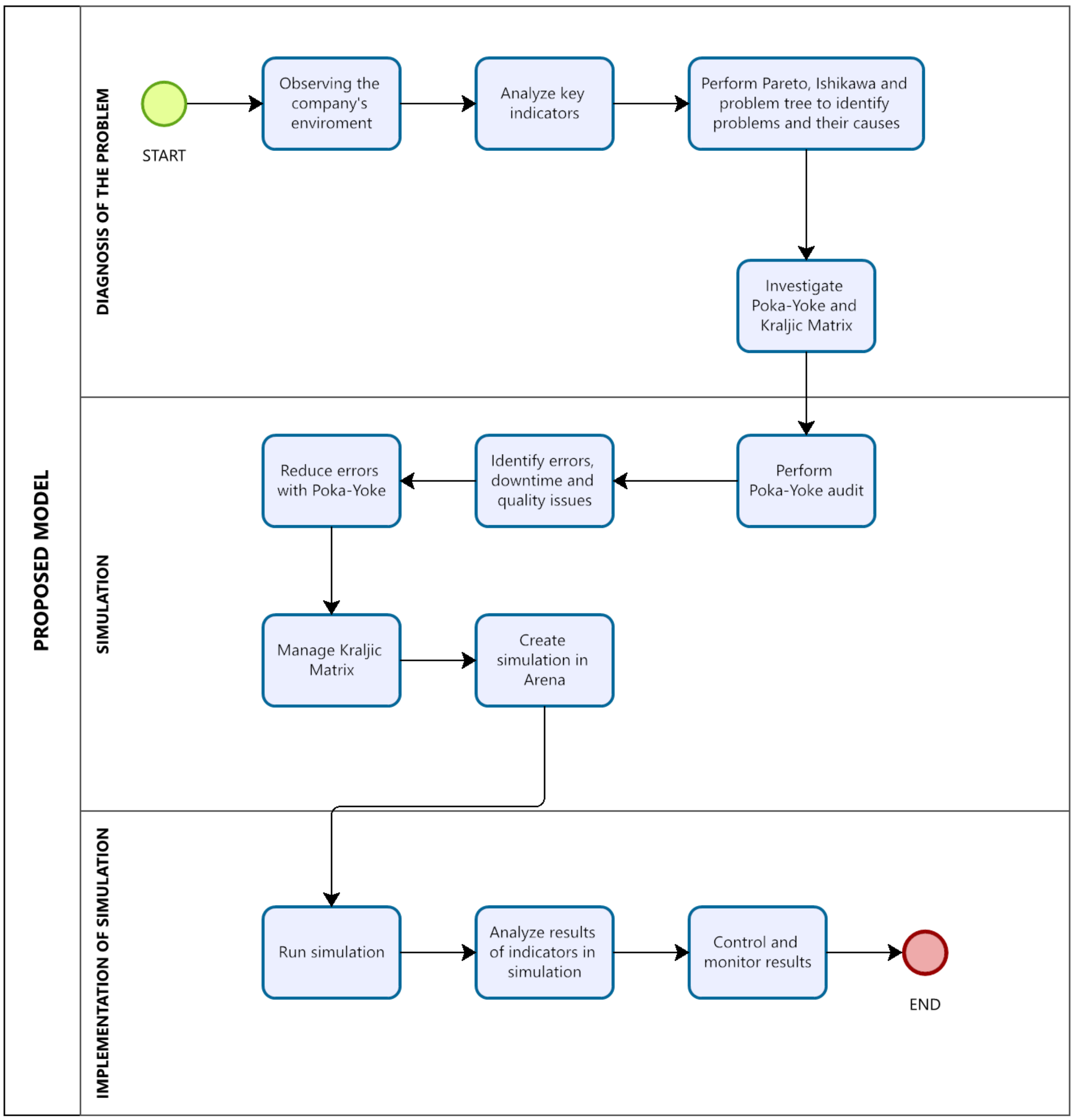


Figure 2. Database for analysis

5. Results and Discussion

5.1 Numerical Results

This thematic axis is linked to Objective 2: Conduct the analysis and diagnosis of the problem using industrial engineering tools. The proposed hypothesis suggests that the implementation of the proposed improvements will increase operational efficiency in the logistical processes. To evaluate this hypothesis, the cycle times of the logistical activities before and after the implementation of the improvements (Table 1- Table 3).

Table 1. Comparison of cycle times before and after the improvement.

Activities	Average Time (min) - Before Improvement	Average Time (min) - After Improvement
Toasting	19.090	16.442
Grinding	0.080	0.071
Weighing	0.458	0.434
Packaging	1.395	0.214
Weight Check	0.249	0.426
Sealing	0.255	0.850

Then, objective 4: Validate the solution, evaluate its economic viability and its impact on relevant stakeholders. The hypothesis also addresses the positive economic impact expected from the improvements. To evaluate the economic impact, the costs associated with the processes were analyzed logistics before and after the implementation of the improvements, as well as the losses economic losses due to late deliveries.

Table 2. Comparison of costs before and after the improvement.

Concept	Before Improvement ($)	After Improvement ($)
Operating Costs	30,000	25,000
Losses due to late deliveries	45,600	10,000
Total	**75,600**	**35,000**

Respect to customer satisfaction to Objective 3: Design and develop proposals for solution that optimizes the supply chain, focusing on the level of service and customer satisfaction. Surveys were conducted with customers to measure their satisfaction before and after the implementation of the improvements. Below are the survey results:

Table 3. Customer satisfaction level before and after the improvement.

Indicator	Formula	As Is	To be	% increase
On-Time Deliveries	$\frac{\text{Number of on} - \text{time deliveries}}{\text{Number of orders received}} * 100$	49.71%	76.97%	18.26%

5.2 Graphical Results

Based on this study (Figure 3- Figure 5), it can be concluded that the variable that most affects all indicators is the selling price. Moreover, it can be stated that the Net Present Value (NPV) will always be positive, as with 90% confidence, it ranges between S/.34,398 and S/.20,162. Regarding the Internal Rate of Return (IRR), it will always exceed the Cost of Capital Opportunity (CCO), with values ranging between 81.3% and 123.9%, which means that in all cases it is greater than the CCO (12.5%).

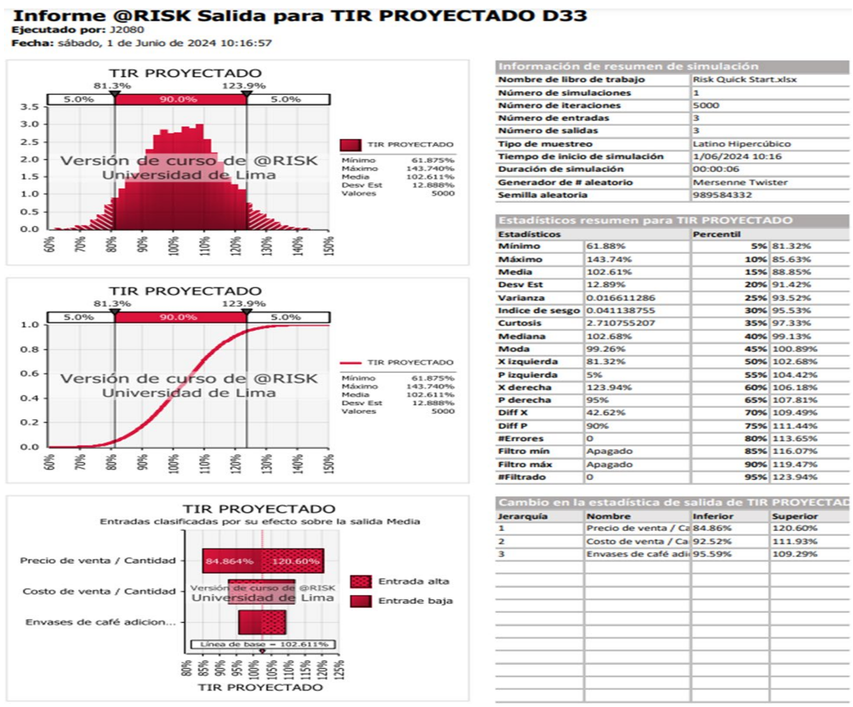
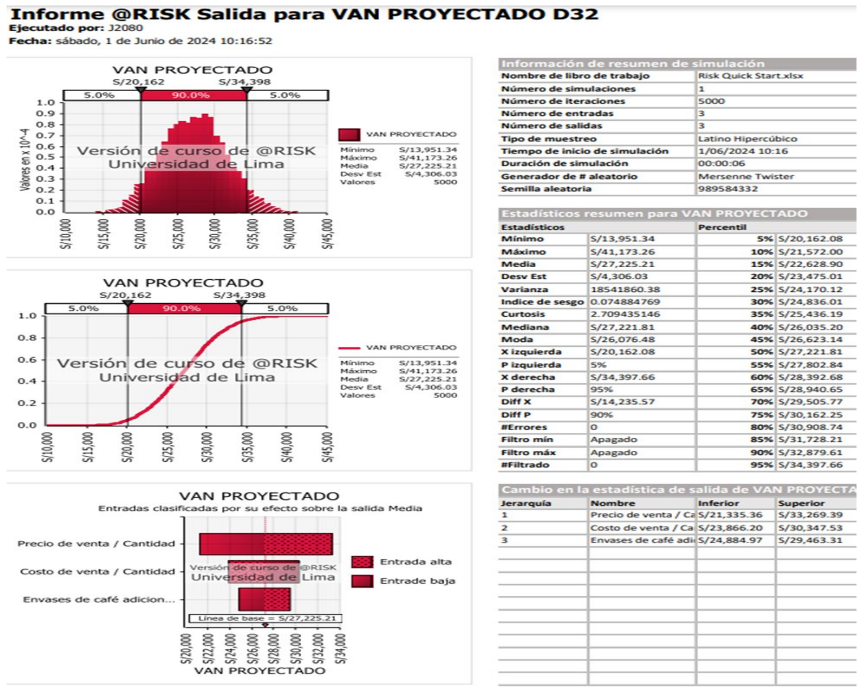


Figure 3. Departure Report for PROJECTED VAN D32

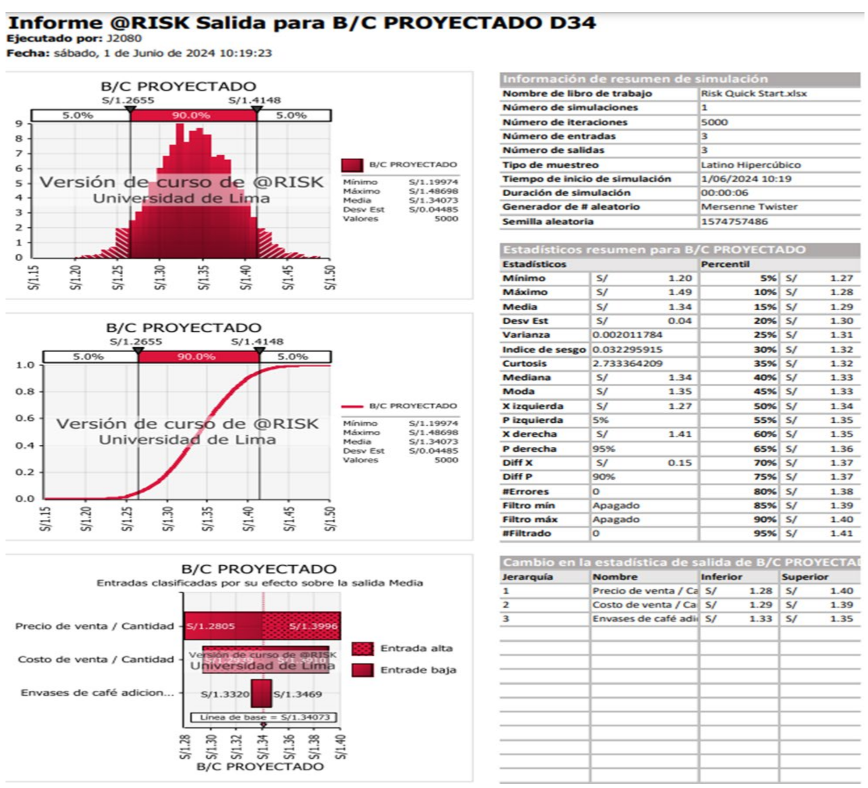


Información de resumen de simulación	
Nombre de libro de trabajo	Risk Quick Start.xlsx
Número de simulaciones	1
Número de iteraciones	5000
Número de entradas	3
Número de salidas	3
Tipo de muestreo	Latino Hipercúbico
Tiempo de inicio de simulación	1/06/2024 10:16
Duración de simulación	00:00:06
Generador de # aleatorio	Mersenne Twister
Semilla aleatoria	989584332

Estadísticos resumen para VAN PROYECTADO			
Estadísticos		**Percentil**	
Mínimo	S/13,951.34	5%	S/20,162.08
Máximo	S/41,173.26	10%	S/21,572.00
Media	S/27,225.21	15%	S/22,628.90
Desv Est	S/4,306.03	20%	S/23,475.01
Varianza	18541860.38	25%	S/24,170.12
Indice de sesgo	0.074884769	30%	S/24,836.01
Curtosis	2.709435146	35%	S/25,436.19
Mediana	S/27,221.81	40%	S/26,035.20
Moda	S/26,076.48	45%	S/26,623.14
X izquierda	S/20,162.08	50%	S/27,221.81
P izquierda	5%	55%	S/27,802.84
X derecha	S/34,397.66	60%	S/28,392.68
P derecha	95%	65%	S/28,940.65
Diff X	S/14,235.57	70%	S/29,505.77
Diff P	90%	75%	S/30,162.25
#Errores	0	80%	S/30,908.74
Filtro mín	Apagado	85%	S/31,728.21
Filtro máx	Apagado	90%	S/32,879.61
#Filtrado	0	95%	S/34,397.66

Cambio en la estadística de salida de VAN PROYECTA			
Jerarquía	**Nombre**	**Inferior**	**Superior**
1	Precio de venta / Ca	S/21,335.36	S/33,269.39
2	Costo de venta / Ca	S/23,866.20	S/30,347.53
3	Envases de café adi	S/24,884.97	S/29,463.31

Figure 4. Departure Report for PROJECTED TIR D33



Información de resumen de simulación	
Nombre de libro de trabajo	Risk Quick Start.xlsx
Número de simulaciones	1
Número de iteraciones	5000
Número de entradas	3
Número de salidas	3
Tipo de muestreo	Latino Hipercúbico
Tiempo de inicio de simulación	1/06/2024 10:19
Duración de simulación	00:00:06
Generador de # aleatorio	Mersenne Twister
Semilla aleatoria	1574757486

Estadísticos resumen para B/C PROYECTADO			
Estadísticos		**Percentil**	
Mínimo	S/ 1.20	5%	S/ 1.27
Máximo	S/ 1.49	10%	S/ 1.28
Media	S/ 1.34	15%	S/ 1.29
Desv Est	S/ 0.04	20%	S/ 1.30
Varianza	0.002011784	25%	S/ 1.31
Indice de sesgo	0.032295915	30%	S/ 1.32
Curtosis	2.733364209	35%	S/ 1.32
Mediana	S/ 1.34	40%	S/ 1.33
Moda	S/ 1.35	45%	S/ 1.33
X izquierda	S/ 1.27	50%	S/ 1.34
P izquierda	5%	55%	S/ 1.35
X derecha	S/ 1.41	60%	S/ 1.35
P derecha	95%	65%	S/ 1.36
Diff X	S/ 0.15	70%	S/ 1.37
Diff P	90%	75%	S/ 1.37
#Errores	0	80%	S/ 1.38
Filtro mín	Apagado	85%	S/ 1.39
Filtro máx	Apagado	90%	S/ 1.40
#Filtrado	0	95%	S/ 1.41

Cambio en la estadística de salida de B/C PROYECTAI			
Jerarquía	**Nombre**	**Inferior**	**Superior**
1	Precio de venta / Ca	S/ 1.28	S/ 1.40
2	Costo de venta / Ca	S/ 1.29	S/ 1.39
3	Envases de café adi	S/ 1.33	S/ 1.35

Figure 5. Departure Report for B/C PROJECTED D34

The proposed solution evaluated the impacts of implementing the Kraljic matrix and the Poka-Yoke, Supplier Scorecard, and CMI dashboard tools in the supply chain management of a Peruvian coffee company on the stakeholders. An evaluation was conducted on the impact of implementing these techniques on the stakeholders involved in the project's development. Likewise, the respective impact matrix was applied to evaluate its influence on the project. Through this evaluation, the stakeholders who were influenced in the development of the project were identified.

5.3 Proposed Improvements

The analysis and the proposed solution constitute essential and crucial elements of utmost importance for addressing the identified logistical challenges. In this context, the deployment of three key industrial engineering tools in the case study stands out. These tools are: These tools are the Balanced Scorecard (BSC), the SCOR model (Supply Chain Operations Reference), as well as the Poka Yoke method, complemented by MEDAL (Logistics Management Evaluation and Diagnosis Methodology) and the Kraljic Matrix.

This deployment of tools represents a comprehensive strategy to understand and address logistical challenges, establishing a solid foundation for the effective implementation of specific solutions. The interrelation between these tools translates into a coherent and well-structured approach, where each one plays a key role in identifying root causes, analyzing processes, and formulating improvement proposals.
Process analysis

In process analysis, Poka Yoke will examine the stage of the process to be improved, that is, it will identify the most frequent and costly errors, with delays in order delivery being a highlighted problem. This delay is attributed to transportation issues, such as breakdowns, accidents, thefts, among others. This inconvenience directly impacts the percentage of on-time deliveries, which is the KPI we aim to improve, as will be explained later. A possible cause of this error is the lack of control and monitoring of transportation, which prevents anticipating and resolving any issues that may arise along the way. MEDAL emphasizes the importance of thoroughly understanding each of the internal processes related to the research area and comprehending the current problems that affect its performance today.
Application of the Master Experimentation Plan

-In this section, the level of application of the proposed Master Experimentation Plan must be explained, showing evidence of the development of the planned stages. Examples of evidence regarding the level of implementation of the master plan are:

- Progress Reports of the experimentation plan
- Records (photos, videos, interviews, etc.) of the activities carried out during the implementation.
- Emails, meeting minutes, and other communications that document the collaboration and coordination between the members of the experimentation team and the stakeholders.
- Examples of products or tangible results that have been developed as part of the experimentation, such as prototypes, analysis reports, procedure manuals, among others.
- Results of tests and validations carried out to verify the functioning and effectiveness of the proposed solutions.
- Satisfaction surveys, comments, and feedback from the staff involved in the production process regarding the effectiveness of the proposed improvements.
- Performance Indicators (KPIs) and metrics that demonstrate the impact of improvements on process performance, such as increased productivity, reduced costs, improved quality, etc.
- Results of external audits or quality reviews conducted by third parties to validate compliance with relevant standards and regulations.
- Records of participation in training and development sessions for the staff involved in the proposed improvements.

5.4 Validation

Design of functional validation: Obtaining the representative sample of the case study.
The identified unit of analysis for this project is a batch of 1000 kg of green coffee, considering that it represents a typical production quantity in the selected coffee company. The choice of this unit is based on the need to optimize the logistical processes associated with the acquisition, storage, and distribution of dry parchment coffee, which is the

fundamental raw material in coffee production. To validate the proposed solutions, simulation will be used. After thoroughly reviewing the literature, it was determined that tools such as the Kraljic matrix and supplier scorecards require financial investment and an interruption in operations, making simulation a more viable option. The implementation of the simulation will be carried out using Arena software, for which it is necessary to determine an optimal sample size that ensures the reliability of the project. This will be carried out by calculating the sample size for a finite population, thus allowing for a precise and reliable validation of the proposed strategies to optimize logistical efficiency in the coffee production process. This is how a sample size (N) is chosen: the number of orders between November 2023 and March 2024 is 1450 for green coffee. For the calculation, the following parameters were considered:

-Confidence level (Z): 95%
-Sample error (e): 5%
-Heterogeneity (p, q): 50%
The result of this calculation yielded a sample of 161 production orders. This sample will be useful for running the simulation.

Layout of the validation model - Validation by simulation
To validate the effectiveness of the proposed solutions in optimizing the supply chain in coffee production, the simulation technique will be used. Based on the data collected during visits to the company and the observation of the manufacturing process, a simulation model was developed that accurately represented the activities of the production process, as well as the sequence of operations and the decision logic involved.

The simulation model will focus on the coffee production process, from the reception of raw materials to the packaging of the final product. For this, the times between the arrival of inputs, processing activities such as roasting and grinding, and the stages of packaging and storage will be considered (Table 4).

Table 4. Parameters of the Coffee Production Simulation Model.

Resource	Attributes	Activities
Dry parchment coffee	Time of arrival at the system	Enter system 1
		Form queue 1
Operator of the toasting area	Time of operation in the toasting area	Occupy operator (m=1,2)
		Place the grains of coffee in the toasting machine
		Remove and transfer the toasted coffee
		for its subsequent stage
Toasted coffee	Waiting time for grinding	Form queue 2
Grinding area machine	Time of operation in the grinding area	Wait for the toasted coffee
		Perform the grinding of the coffee
		Transfer the ground coffee for its next stage
Weighing area machine	Time of operation in the weighing area	Perform the weighing of the coffee
Packaging area machine	Time of operation in the packaging area	Perform the packaging of the coffee in recipients
Inspection area operator	Time of inspection in the inspection area	Verify the weight of the coffee
		Transfer the verified coffee to the sealing stage
Sealing area machine	Time of operation in the packaging area	Perform the sealing of the packaged coffee with its label

To validate the simulation model, a comparison will be made between the current situation of the company's production process and the proposed situation with the new times obtained after implementing improvements. The following indicators will be used to measure the impact of the improvements:

-Cycle time: It measures the total duration of the process from the arrival of the raw material to the distribution of the sealed coffee.

-Productivity: Calculate the ratio between the number of coffee bags processed and the total time invested in the production process.

-Efficiency of each stage: Evaluate the efficiency of each stage of the process, considering the time spent and the processing capacity.

-Product quality: Evaluates the quality of the processed coffee, considering the proportion of defective products or those that do not meet quality standards.

-Delivery on time: Measures the percentage of production orders completed on time, considering the target time for each stage.
The presentation of a completed validation model is not expected, but a diagram in the selected tool that can identify the level of complexity of the proposed design should be presented.

Through this approach, the standard deviation of the system output data (key indicators) was analyzed in "Analyze" using the "Confidence Interval" function of the Output Analyzer software, setting it to "Classical Confidence Interval on Mean." This allowed us to determine the confidence intervals and calculate the number of replications needed for each relevant indicator of the simulation model.

6. Conclusion

The research successfully achieved its objective. The implementation of Poka-Yoke principles demonstrably reduced human error and improved efficiency throughout the production process, as evidenced by significant reductions in average processing times across various stages (e.g., packaging time decreased from 1.395 minutes to 0.214 minutes). This, coupled with the application of the Kraljic Matrix to optimize supplier selection and streamline the flow of finished products, led to substantial improvements in operational performance. The positive impact is further substantiated by the improvement in on-time deliveries and a significant reduction in operating costs and losses due to late deliveries. The combined effect of these strategies demonstrably improved the overall efficiency and effectiveness of the coffee production process.

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