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DMAIC as a tool to implement an improvement system to increase productivity in the hat industry

DMAIC como herramienta para implementar un sistema de mejora paraincrementar la productividad en la industria del sombrero

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ABSTRACT

Keywords:

DMAIC, Garment Industry, Maquiladoras, Lean Manufacturing

This study is an applied research that aims to diagnose the hat maquiladora industry in the region of Tehuacán, Puebla, Mexico and, based on this, adapt the Lean Manufacturing philosophy as a strategy to remain within the globalized market supported by the DMAIC tool. To this end, a diagnosis was made in the maquiladora companies applying a series of questionnaires to determine the causes that generate the low productivity of this sector. Subsequently, the variables that affect productivity were quantified, followed by an analysis and integration of systems for improvement and control of methods to guarantee the permanence of this type of company in a globalized market. The results of the questionnaires showed a very critical situation that explains the low level of competitiveness that prevails within this type of company and, based on these design results, an improvement system was designed.

RESUMEN

Palabras clave:

DMAIC, Industria del vestido, Maquiladoras, Manufactura Esbelta

El presente estudio es una investigación aplicada que tiene como objetivo el diagnóstico de la industria maquiladora del sombrero en la región de Tehuacán, Puebla, México y con base a ello adaptar la fi losofía de Manufactura esbelta como una estrategia para permanecer dentro del mercado globalizado apoyado en la herramienta DMAIC, para ello se elaboró un diagnostico en las empresas maquiladoras aplicando una serie de cuestionarios para determinar las causas que generan la baja productividad de este sector, posteriormente se cuantifi có las variables que afectan a la productividad continuando con un análisis e integración de sistemas de mejora y control de los métodos para garantizar la permanencia de este tipo de empresas en un mercado globalizado, los resultados de los cuestionarios arrojaron una situación muy crítica que explica el nivel bajo de competitividad que prevale dentro de este tipo de empresas y con base a dichos resultados de diseño un sistema de mejora.

1. Introduction

For a long time, the hat industry in Tehuacan's maquiladoras has been managed as family businesses, regardless of the size or type of product they process. The companies lack clarity regarding their mission, vision, and objectives, which means they are unaware of techniques, systems, tools, or philosophies available in the market that they could adapt. States such as Puebla, Veracruz, Campeche, Guerrero, and Oaxaca are known for their significant contribution to the production of handmade hats woven from palm leaves. The palm plant serves as the raw material for weaving the hats. Tehuacan, Puebla, is a significant location for the hat industry due to its proximity to communities engaged in hat weaving and suppliers of raw materials, such as straw, located in the surrounding areas of Mixteca poblana and Oaxaca. This industry is one of the most important in the state of Puebla, generating thousands of products, distributed throughout the country, which demand higher quality every day.

A lean company is one that achieves continuous improvement in all of its processes, both administrative and manufacturing. These improvements are achieved by incorporating philosophies into the corporate culture that enable the implementation of projects that address the root problems of companies that affect processes, products, and the organizational environment [1].

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Companies aim to strategically position themselves in the global market, which can be achieved through the implementation of Lean Manufacturing. It is essential for companies to understand and use the tools and techniques developed under this philosophy, which collectively aim to eliminate waste. However, Lean thinking offers benefits beyond waste reduction, and it is important to explore these aspects as well.

The aim of this work is to implement an integrated manufacturing system in the hat maquiladora industry's production processes in the Tehuacán region. To achieve this, a qualitative approach of causal correlation type is used, based on the research problem and proposed objectives. This study has a broad explanatory scope as it examines the relationship between the implementation of an integrated manufacturing system in production processes and the strengthening of business strategies.

The study employed both theoretical and practical methods to create tools for gathering timely information [3]. These tools consisted of an interview guide, a guide for reviewing documents, an observation guide, and focus groups. The production processes were identified as batch processes. Some lean manufacturing techniques, such as Six Sigma, productivity improvement, and the DMAIC cycle, are partially implemented in these processes.

To achieve an effective integrated manufacturing system, it is necessary to strengthen internal administrative control and implement the proposed strategic plan. The plan should be based on corporate functions and strategies, ensuring the documentation of all information generated in the production processes. This documentation will assist senior management in making informed decisions [4].

There are various methodologies for analyzing and solving problems. However, not all of them provide the necessary tools for this purpose. Some focus on reducing waste without performing a statistical analysis, such as Lean Manufacturing, while others use statistics to improve processes without considering waste, such as Six Sigma [5]. The Lean Six Sigma methodology combines the statistical approach of Six Sigma with the waste reduction techniques of Lean to solve problems [6]. This project is based on the DMAIC application, which is mainly supported by the 3-level Pareto diagram.

Throughout the development of this project, the characteristics of this tool, its application process and the results obtained are observed. According to Filizzola [7], Six Sigma and Lean Manufacturing are approaches to quality and productivity improvement that have been implemented with great success in large companies worldwide, in the field of manufacturing and services [8]. However, implementing this type of approach in small and medium-sized companies can be challenging, as noted by researchers and experts in the field.

Chávez [9] states that the proper adoption of the Lean production system can improve operational performance by increasing productivity. This adoption requires a change in organizational culture, which can be achieved through an appropriate socio-technical system. The literature suggests that comprehensive adoption of Lean production system practices is preferable to partial adoption. However, there is a lack of consensus on this subject. Therefore, further research is needed to better understand this technique.

Chavarría [10] suggests that companies have experienced production line downtime due to the lack of controls and standards that streamline work and ensure product and process quality. Therefore, he recommends designing and implementing an action plan for continuous improvement using Lean Manufacturing tools, such as 5S and Visual Control. This involves designing and implementing the action plan along with the necessary documentation and assessing its effectiveness.

Piñero [11] suggests that the implementation of the 5S methodology is a powerful tool for continuously improving quality and productivity in the workplace.

García [12] notes that implementing DMAIC to reduce production process waste involves comparing pre- and post-process defect rates with waste generated in production areas. The application of the DMAIC Methodology associated with Six Sigma resulted in workers acquiring individual skills that enhanced their performance. Furthermore, the implementation of tools to enhance error detection through a standardized work method led to improvements in organizational and social communication.

2. Methodology

DMAIC is a systematic tool focused on improving process productivity. This methodology seeks to improve production methods, and it is a process that can be repeated constantly in order to continuously evolve and improve it. The name is an acronym for the steps of the methodology: define, measure, analyze, improve and control, which was developed by Motorola engineer Bill Smith in 1984 [13]. Minitab is the software used to capture information for solving problems in pre-existing processes as part of the Six Sigma management system [14]. The methodology is described in the following paragraphs. The DMAIC analysis involves conducting various studies to make changes and analyze resulting data. These studies include justification of proposals, Pareto Diagram [15], Time Series Analysis [16], Pie Diagram, Type

I Study, R&R Study (ANOVA) [17], Cause-Effect Diagram [18], t-Test, and Effects Graph, among others.

Phase 1. *Define:* The first step is to define the problem that needs to be solved. This is a crucial step as it sets the foundation for establishing the metrics that will be used to track the problem's progress. Defining the problem is essential in determining the quality indicators or key performance indicators (KPIs) that will provide a better understanding of the situation. The employed method was deductive, moving from the general to the specific, to implement an improvement system supported by theoretical principles. This approach can be visualized using a 3-level Pareto diagram or a pie chart. The research analyzed the brands manufactured by the involved companies, focusing on the standard hat. The results, shown in Figure 1, reveal that the most frequently produced hat brand is IGGIS, constituting 80.3% of total production. Using this insight, a secondary diagram was created to identify the most significant issues with this brand.

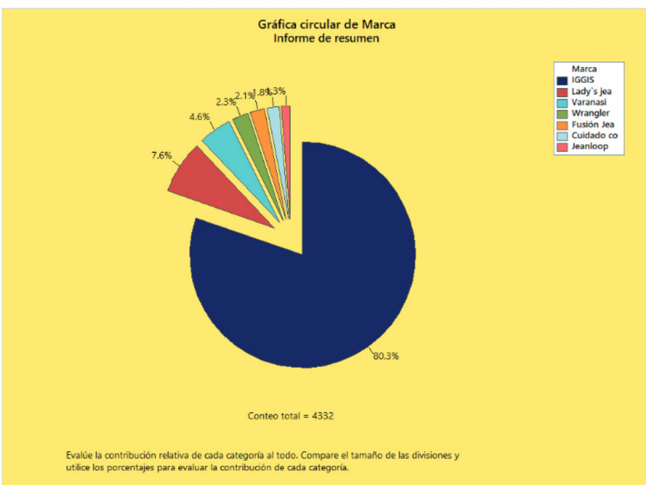

Figure 1. Product Brand.

Figure 2 shows the results of defects in the sizes of the IGGIS brand. The methodology involved identifying the most produced brand and prioritizing that product. The size with the most defects was then identified as size 32.

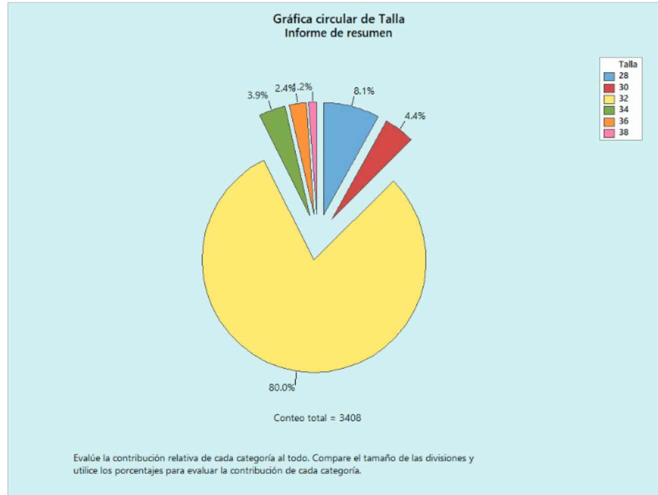

Figure 2. Production sizes.

After identifying the most common size, we proceeded to identify the defects in each size. The most frequent defect was tip variation, as shown in Figure 3.

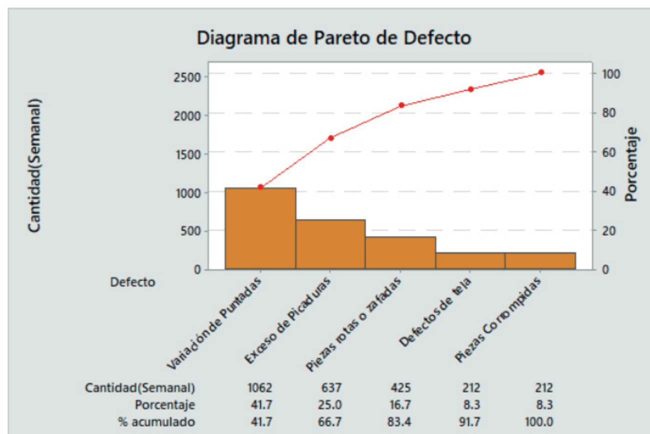

Figure 3. Defects

Figure 4 shows the behavior of this variation. The time series graph shows that the stitches per inch are between 8.5 to 9.62 stitches/plg.

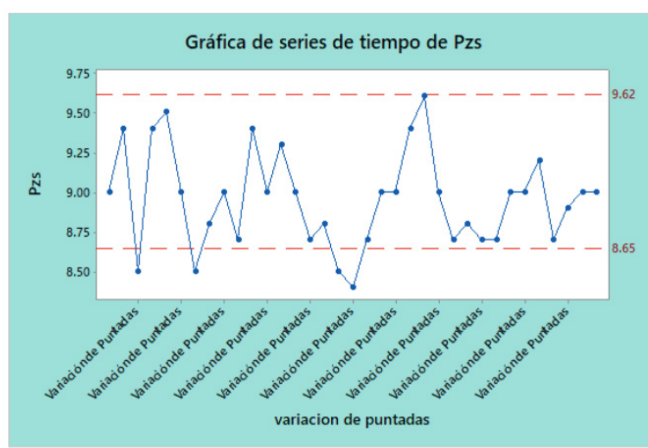

Figure 4. Defect behavior.

The DMAIC methodology suggests that the first step is to define a SMART objective for stitches per inch, which should represent 70% of the gap between the maximum value and the average for the characteristic under control. Subsequently, the focus should shift towards addressing size-related issues, followed by tackling defects in the brands. This approach utilizes an inductive method.

Phase 2. *Measure:* This phase involves measuring variables and establishing a follow-up that will enable further analysis of the situation [19]. The objective of this stage is to measure the current performance of the process to be improved. To achieve this, the first step is to verify that the measuring equipment involved in the process is calibrated, supported by the type 1 study technique. This is used to evaluate the capability of a measurement process. The study assesses the combined effects of bias and repeatability by taking multiple measurements of the same part. It is recommended to perform a type I measurement system study before conducting other repeatability and reproducibility studies to determine the amount of observed process variation due to measurement system variation. The results presented in Figures 5 and 6 were obtained from 2 measurement replicates conducted by 3 operators in the case study.

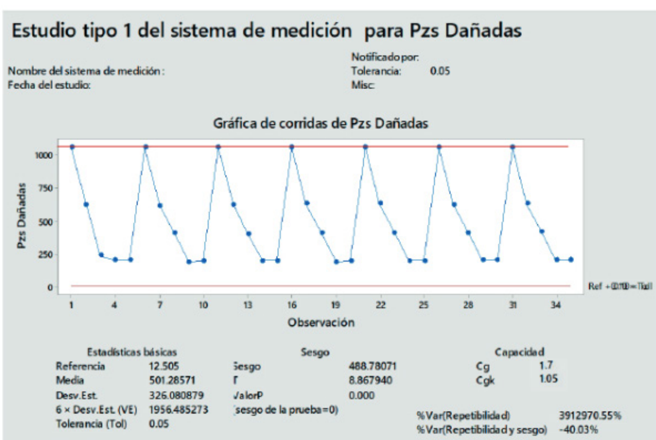

Figure 5. Type 1 study

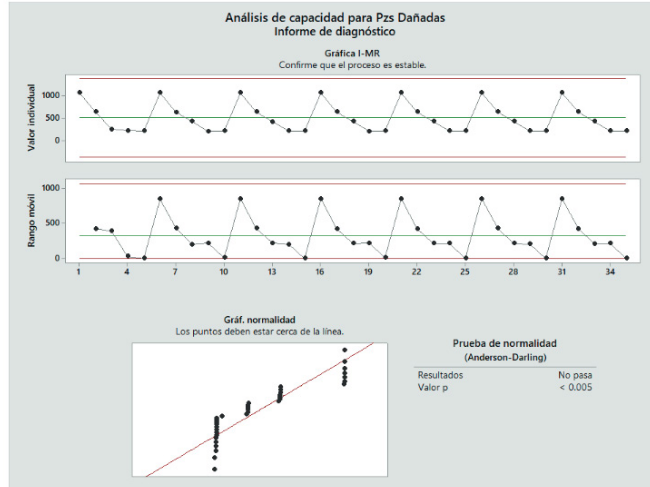

Figure 6. Capacity Analysis.

Figures 5 and 6 demonstrate significant variability among operators and measuring equipment. Therefore, it is recommended to first adjust the measuring equipment and train personnel. Once the measurement equipment and personnel are trained, an R&R study supported by the Internet of Things [20] of the variable under analysis is carried out. Following the case study, the results obtained are shown in Figures 7 and 8.

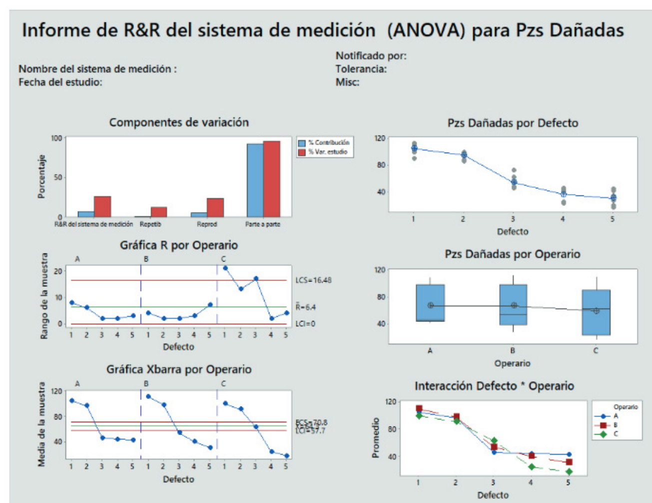

Figure 7. R&R study

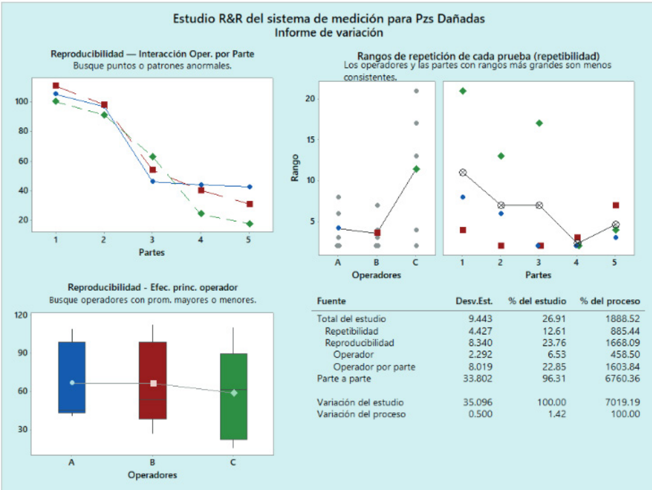

Figure 8. R&R study summary

Phase 3. *Analyze:* Using the data collected in phase 2, an analysis is conducted to determine the causes of system malfunctions and identify areas for improvement.

The main issue is the inconsistency in tips per inch. To identify the root cause, a cause and effect diagram was created, revealing the findings presented in Figure 9.

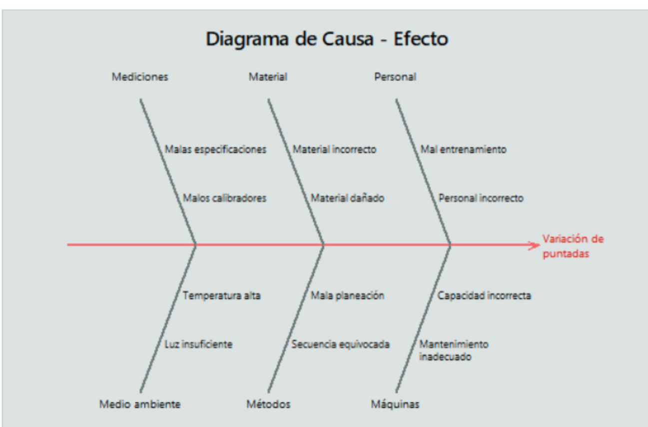

Figure 9. Cause-effect diagram

In this phase, another tool utilized was the two-sample t-test since the variability of the variable is unknown. The results showed atypical data in samples 6 and 8, indicating the need to review the process to determine the cause (refer to Figure 10 and 11). The variables analyzed were machine vs. damaged stitches. In conclusion, it can be stated that the machine has no effect on the damaged stitches. Therefore, efforts should be focused on the needle. Furthermore, Figure 10 suggests that sample sizes larger than 15 should be used to reduce variation between samples, given that it is a highly repetitive process.

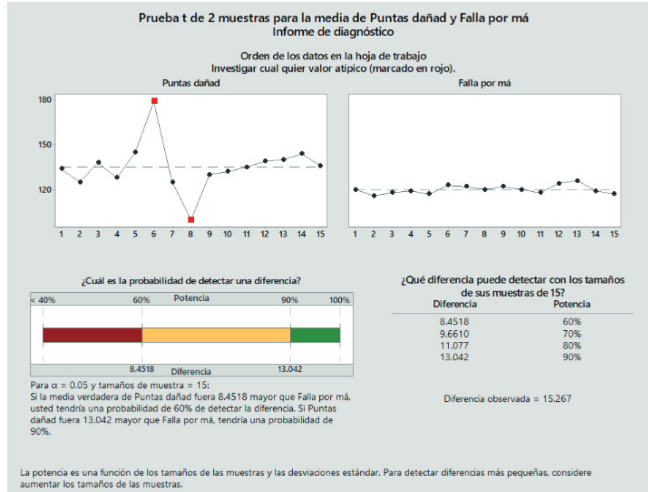

Figure 10. T-test

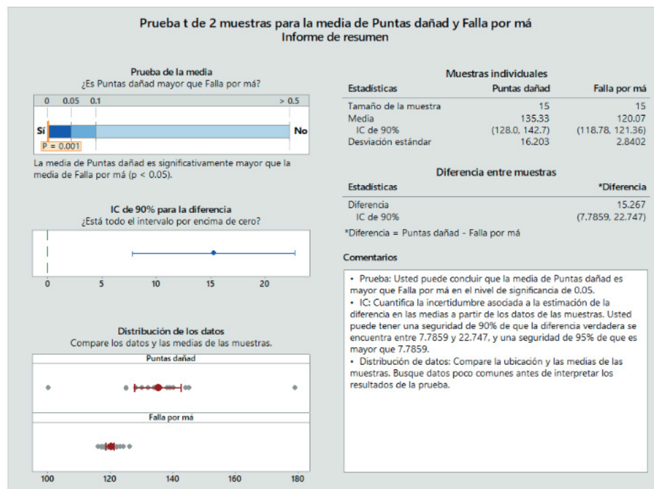

Figure 11. T-test summary

Phase 4. *Improve:* During this phase, actions are taken to improve the current situation. Solutions are designed to address the root problem and meet the customer's expectations, resulting in improvements.

To minimize the impact of yarn variation on the process, it is recommended to concentrate on maintaining a consistent yarn tension of 3,182 units (refer to Figures 12, 13, and 14).

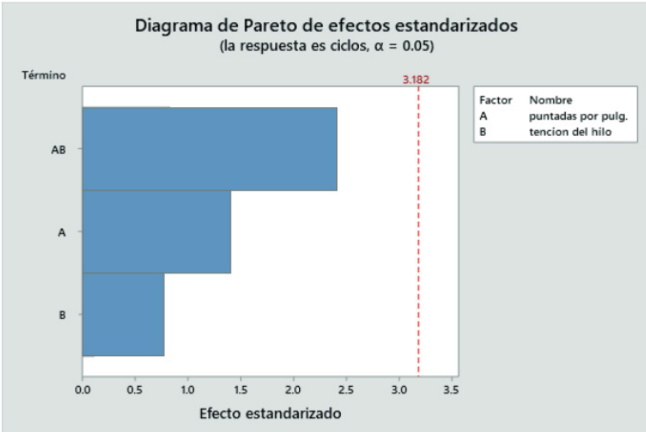

Figure 12. Pareto Chart

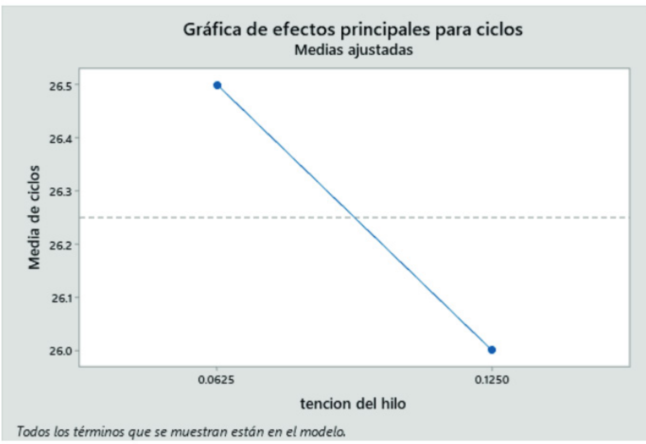

Figure 13. Effect diagram

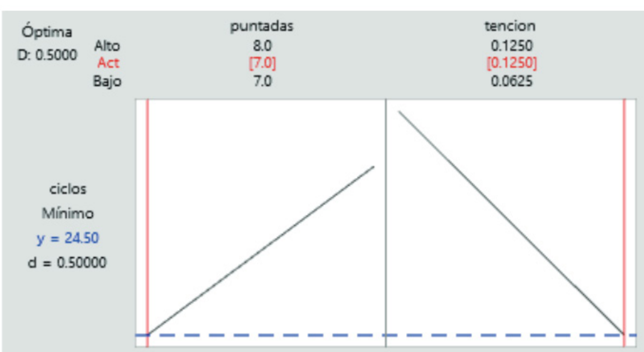

Figure 14. Number of cycles

Phase 5. *Control:* After completing these actions, a control must be implemented to ensure their correct implementation and the achievement of the set objectives. Additionally, it is important to maintain the new course of the process. The results of implementing the improvement system are shown in Figures 15 and 16.

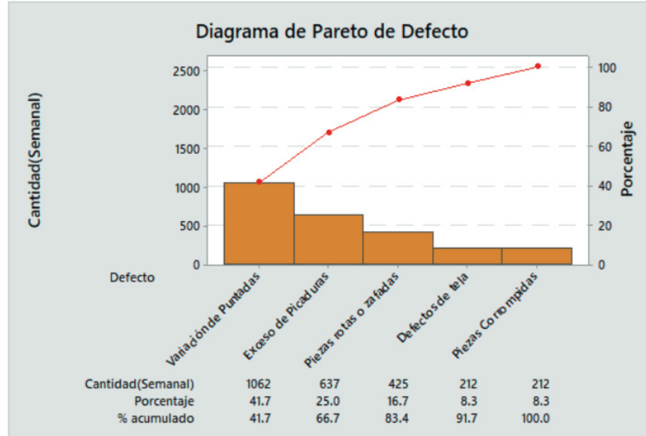

Figure 15. Cumulative percentages

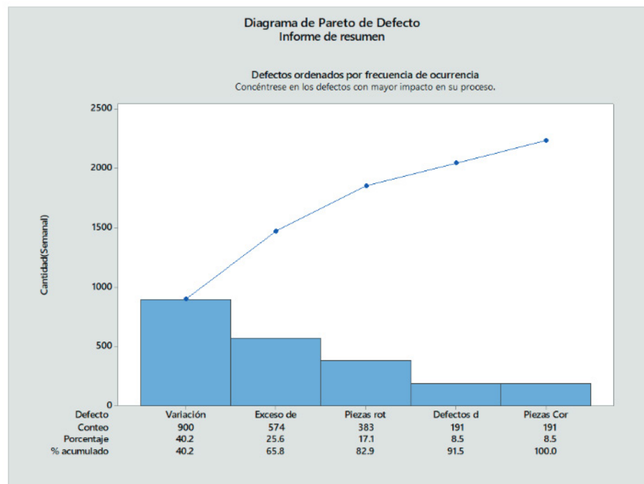

Figure 16. Pareto Chart Summary

3. Discussions

Based on the sources consulted, DMAIC, Six Sigma, and Lean Manufacturing are widely recognized as effective tools for enhancing productivity in various industries. However, there is no evidence of their implementation in the hat maquiladora industry. The sources provide guidance on how to adapt these tools to the specific needs of the analyzed companies. Based on the tests conducted, it has been concluded that flexible technology can be adopted in companies. Therefore, it is recommended that companies of any size or sector implement these tools.

4. Conclusions

The quality of failure control information depends on several critical factors. These factors have been determined through the opinions of experts and end-users' complaints. Based on the above, information must be reliable, consistent, and delivered in a timely manner to enable effective decision-making. This includes planning and resource allocation based on the obtained results, as well as corrective and preventive actions on the process. Quality criteria for failures must be verified within the process. Ideally, the process should not proceed if the quality criteria are not met during the machine setup.

The main obstacles to the success of the project that have been identified include: lack of awareness regarding the importance of timely delivery, lack of commitment by personnel to continuous improvement, resistance to proper recording of all activities, and logistical limitations for follow-ups. During the analysis of the scatter graphs, it was observed that there is an unusual behavior between the variables of the brand of pants and size. This is due to errors in the measurement scales used in the records, which do not show a significant difference between sizes. The cause-effect analysis has grouped the possible causes and subcategories of the failures presented by the pants. The stitch variation is considered vital to guide the process towards continuous improvement. Furthermore, the variable number of errors per record behaves as a normal variable, allowing for the direct application of control charts by attribute. These results were analyzed using hypothesis tests, and the control charts show the findings, making it easier to identify the causes based on the analyzed data.

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