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Quality assurance in the garment industry: Diagnosis and improvement

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ABSTRACT

This research to design innovative textiles with artificial intelligence inspired by traditional

This article examines the multifaceted nature of quality assurance in the garment industry, highlighting its critical role in meeting consumer expectations and ensuring product reliability within a competitive market. It addresses the challenges faced by both consumers and manufacturers when quality is compromised, illustrated through real-world examples of product defects. Emphasizing that quality is defined by customer perception rather than supplier claims, the study aligns with ISO 8402's definition of quality.

The research presents a comprehensive analysis of current quality assurance processes in garment manufacturing, identifying key factors influencing fabric quality, such as material selection, production techniques, and inspection methodologies. Advanced diagnostic tools, including statistical process control and root cause analysis, are employed to identify common defects and their origins in the production workflow.

Additionally, a framework for continuous improvement is proposed, integrating methodologies like Total Quality Management (TQM) and Six Sigma to enhance quality assurance efforts. The implementation of automated inspection technologies and data-driven decision-making is discussed as a means to increase efficiency and reduce variability in fabric quality. By developing a comprehensive quality manual and automated tools for managing non-conformance, this study aims to provide valuable insights for enhancing operational efficiency and market competitiveness in the textile sector, fostering a culture of quality throughout the supply chain.

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ضمان الجودة في قطاع صناعة الملابس: التشخيص والتحسين

ثرية الحمدي [1]

الملخص:

تتناول هذه المقالة الجوانب المتعددة لضمان الجودة في صناعة الملابس، مُسلطةً الضوء على دورها المحوري في تلبية توقعات المستهلكين وضمان موثوقية المنتج في سوق تنافسية. كما تتناول التحديات التي يواجهها كل من المستهلكين والمصنعين عند انخفاض الجودة، مُوضحةً ذلك بأمثلة واقعية لعيوب المنتجات. وبالتأكيد، تُعرّف الجودة من خلال تصور المستهلك وليس من خلال ادعاءات المورد، وتتوافق هذه الدراسة مع تعريف الجودة الوارد في معيار.ISO 8402

يقدم البحث تحليلاً شاملاً لعمليات ضمان الجودة الحالية في صناعة الملابس، مُحدداً العوامل الرئيسية المؤثرة على جودة الأقمشة، مثل اختيار المواد، وتقنيات الإنتاج، ومنهجيات الفحص. تُستخدم أدوات تشخيصية متقدمة، تشمل التحكم الإحصائي في العمليات وتحليل الأسباب الجذرية، لتحديد العيوب الشائعة ومصادرها في سير العمل الإنتاجي.

بالإضافة إلى ذلك، يُقترح إطار عمل للتحسين المستمر، يدمج منهجيات مثل إدارة الجودة الشاملة (TQM) ومنهجية ستة سيجما لتعزيز جهود ضمان الجودة. وتُناقش الدراسة تطبيق تقنيات الفحص الآلي واتخاذ القرارات بناءً على البيانات كوسيلة لزيادة الكفاءة وتقليل التباين في جودة الأقمشة. ومن خلال تطوير دليل شامل للجودة وأدوات آلية لإدارة حالات عدم المطابقة، تهدف هذه الدراسة إلى تقديم رؤى قيّمة لتعزيز الكفاءة التشغيلية والقدرة التنافسية في سوق صناعة النسيج، وترسيخ ثقافة الجودة في جميع مراحل سلسلة التوريد.

الكلمات المفتاحية:

ضمان الجودة، صناعة الملابس، تحسين العمليات

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1. Introduction

1.1 Background

Quality assurance is becoming more and more significant in modern textile production in the face of increasing consumer demand for high-quality products and tough global competition. The manufacture of textiles involves the sequential integration of numerous processes from the preparation of the initial materials through to the fabrication of the textiles, treatment processes and, finally, the assembly of garments. Each of the processes within these stages represents a source of variability with potential defects in the final product, which may have an adverse effect on performance and customer satisfaction. So, how can textile manufacturers balance quality and productivity, and all at affordable costs?
We all know how a single hole, stain, thread break, width or length deviation or distortion can be caused at various stages of the production process, whether it be in weaving or knitting, the treatment process, sewing, drying or washing. And if the causes of these defects are not quickly discovered, it can lead to the downgrading of products that need to be reworked or re-treated or, worse still, scrapped – and at great financial cost. To avoid this, quality-assurance practices, with the use of tests, analysis and procedures are structured into a quality-assurance system within the company using quality-assurance diagnostic tools, statistical methods and procedures. However, the classical tools for assessing process quality such as the Statistical Process Control (SPC) method, the Pareto method and the methods of analysis of defects and root-cause analysis are only effective in assessing the operational conditions of a process. The use of automated detection systems based on new digital technologies, including artificial intelligence and machine learning, open up new approaches for quality assurance and predictive maintenance of textile production. Thus, the textile sector needs a new approach based on the integrated use of methods of statistical process control, diagnostic tools using intelligent methods based on artificial intelligence and machine learning, and good operating practices for process control with a view to permanent improvement, reduction in non-quality costs and, consequently, better global competitiveness.

1.2. Research Questions

This research addresses the following key questions:
1. Identify the primary origins of quality defects in a textile production facility.
What tools or statistical methods would be useful to identify and rank-and-file the types of errors and defects in our codebase?
3. What opportunities exist to make changes that will reduce quality loss and yield gain?

1.3 Research Objectives

This research aims at investigating the quality assurance activities within the textile production platforms and proposing an integrated solution to improve the quality.
The specific objectives are:
• To diagnose the main quality problems occurring in textile manufacturing processes.
• To identify the most critical defects using statistical analysis tools.
• To analyze the root causes of quality deviations in production workshops.
• To propose corrective and preventive actions aimed at improving quality performance.
• To establish a quality assurance system, using statistical, analytical and procedural methods.

2. Methodology

2.1. Research Design

Quality issues in textile manufacturing process Objectives Methodology Approach The current study was carried out using qualitative and analytical methodology for the identification and analysis of defects in the textile manufacturing process and proposing improvement solutions. For this purpose, the research approach used is related to the application of methods and tools of quality management for the solving of industrial problems. Different quality management tools such as Pareto chart, cause and effect diagram, standard operating procedures and process flowcharts have been integrated. The purpose of this is to have a detailed investigation of the problems that may arise during production and to recognize the factors affecting the quality of the products. Therefore, the research methodology used here diagnoses and analyzes the defects and prioritizes them and also recommends measures to eliminate the defects to enhance the performance of the manufacturing process.

2.2. Expert Sample

The analysis presented in this research is based on knowledge extracted from experts working in the textile manufacturing industry. The expert panel consists of process managers, quality controllers and technical staffs with in-depth working knowledge of the textile manufacturing process.
The experts were engaged in the identification of the most frequently occurring defects, verification of the causes of defects, and evaluation of the proposed improvement measures. Their expertise in production management and quality assurance gives an insight into the practical problems which arise in textile production.

2.3. Data Collection Tools
A variety of tools were employed to collect and organize the data concerning the defects of products and processes.
2.3.1. Pareto chart
A pareto chart is a graphical tool used to identify and visualize the most significant factors in a dataset. It is based on the **pareto principle**, which states that approximately 80% of effects come from 20% of the causes. This principle is often summarized as the "80/20 rule."
2.3.1.1. Key components of a pareto chart
In a chart, each bar represents a specific problem, defect, or category, arranged in descending order based on frequency or impact, with the tallest bars indicating the most significant issues. Additionally, a cumulative line graph is overlaid on the bar chart to illustrate the cumulative percentage of the total, helping to visualize the proportion of total problems accounted for by the most frequent causes.
2.3.1.2. Purpose and benefits
A Pareto chart is primarily used to prioritize issues based on their impact, enabling organizations to allocate resources more effectively to address the most significant problems. It aids in identifying the "vital few" causes that contribute most to an issue, allowing teams to focus their improvement efforts accordingly. Additionally, the chart offers a visual representation that facilitates data-driven decision-making, making it easier to communicate findings to stakeholders.
2.3.1.3. Applications
A Pareto chart is a powerful tool widely used in quality management to identify the main defects in processes, products, or services. It is instrumental in root cause analysis, helping to pinpoint areas that require corrective actions. Additionally, the chart aids project management by assessing risks or issues that need immediate attention. By leveraging the insights gained from a Pareto chart, organizations can enhance efficiency, improve quality, and ultimately achieve better results.
2.3.2. Cause and effect diagram
A cause and effect diagram, also known as a Fishbone diagram or Ishikawa diagram, is a visual tool used to systematically identify and analyze the potential causes of a specific problem or effect. It helps teams understand the various factors contributing to an issue, facilitating problem-solving and decision-making.
2.3.2.1. Key components
a- Effect

The main problem or effect is placed at the head of the "fish." This is the issue that needs to be addressed.

b- Major categories

Branching off from the main spine of the diagram are several major categories of causes. Common categories include:

- **People**: Issues related to human resources or staffing.
- **Processes**: Problems in procedures or workflows.
- **Materials**: Quality or availability of materials used.
- **Equipment**: Machinery and tools involved in the process.
- **Environment**: External factors that may affect performance.

c- Sub-causes

Under each major category, specific causes are listed that contribute to the main problem. These can be further broken down into sub-causes for more detailed analysis.
2.3.2.2. Purpose and Benefits
The diagram facilitates the identification and categorization of root causes of problems, enabling teams to address underlying issues rather than just symptoms. It offers a clear visual representation of the relationship between causes and effects, making complex issues easier to understand. Additionally, it promotes structured brainstorming and collaborative discussion, allowing team members to share insights and experiences effectively.
2.3.2.3. Applications
A cause and effect diagram is an essential tool for teams aiming to identify the underlying causes of problems, frequently utilized in quality management processes to pinpoint sources of defects or failures. It proves valuable across various fields, including manufacturing, healthcare, and service industries, for systematic problem analysis. Additionally, it aids project management by highlighting potential risks and causes of failure. By visualizing these relationships, organizations can develop targeted solutions that address root causes, resulting in more effective problem resolution and process improvement.

2.3.3. Work procedures

Work procedures are detailed, step-by-step instructions that outline how specific tasks or activities should be performed within an organization. They serve as a guide for employees to ensure consistency, quality, and safety in their work.

2.3.3.1. Key elements of work procedures:

A cause and effect diagram is a valuable tool for teams aiming to uncover the underlying causes of various problems, widely employed in quality management processes to identify sources of defects or failures. This diagram is particularly useful in diverse fields such as manufacturing, healthcare, and service industries, where it facilitates systematic analysis of issues. In project management, it serves as a critical instrument for identifying potential risks by examining the root causes of failures. By visualizing the relationships between different factors, organizations can develop targeted solutions that effectively address these root causes, ultimately leading to enhanced problem resolution and significant improvements in processes.

2.3.3.2. Importance of work procedures

Standard operating procedures (SOPs) play a crucial role in ensuring consistency by guaranteeing that tasks are performed uniformly, thereby reducing variability and minimizing errors. They serve as effective training tools for new employees, helping them to clearly understand their roles and responsibilities within the organization. By providing clear instructions, SOPs streamline processes, which can significantly reduce the time spent on tasks. Additionally, they help ensure compliance with industry regulations and standards, making it easier for organizations to adhere to necessary guidelines. Furthermore, SOPs establish a robust framework for maintaining quality in products and services, ultimately contributing to overall organizational efficiency and effectiveness.

2.3.4. Flowchart for a process

A flowchart is a visual representation of a process, illustrating the sequence of steps involved in completing a task or achieving a goal. It uses various symbols to denote different types of actions or decisions within the process.

2.3.4.1. Key symbols in flowcharts

In a flowchart, various shapes serve distinct purposes to illustrate the process clearly. The oval shape signifies the start and end points of the process, marking where it begins and concludes. Rectangles are used to indicate specific process steps or actions that need to be taken. Decision points within the process are represented by diamonds, which require a yes/no or true/false response to guide the flow. Arrows are essential as they demonstrate the direction of flow, connecting one step to another and showing the sequence of actions. Additionally, parallelograms are employed to represent input or output operations, such as data entry or the results produced, thereby providing a comprehensive view of the entire process.

2.3.4.2. Steps to create a flowchart

a. Define the process

Clearly articulate the process you wish to visualize, outlining each step in detail to ensure a comprehensive understanding of its flow and structure.

b. Identify the steps

Compile a complete list of all steps involved in the process, including both actions and decision points, to capture the full sequence of activities.

c. Determine the sequence

Organize the steps in the sequence in which they occur, ensuring a logical flow that accurately reflects the progression of the process.

d. Choose symbols

Select the appropriate symbols to accurately represent each step and decision in the process, ensuring that they align with standard flowchart conventions.

e. Draw the flowchart

Start with the initial symbol, then sequentially add each step, connecting them with arrows to illustrate the flow of the process.

f. Review and refine

Examine the flowchart for clarity and accuracy, making any necessary adjustments to enhance its effectiveness and comprehensibility.

2.4. Data Analysis Procedure

The data analysis was carried out in a systematic way by applying the principles of quality management. Initially, defects were collected and grouped under various heads and a Pareto analysis was made to classify those defects which had the maximum impact on the quality of the product. The purpose of the analysis was to identify the vital few defects which were contributing to the presence of the trivial many.

Thereafter, the cause and effect diagram was prepared to identify the possible causes of different defects. Various possible causes were highlighted and these are related to human resource, material, method, machine and environment.

Finally, process flowcharts and work procedures were developed to assess the current process and to identify areas for improvement to reduce defects and to improve productivity.

2.5. Integration of Data Sources

Several types of information have been combined to carry out this study.

Data from production records and defect reports, along with expertise and process observations were combined. Various analytical tools were employed to cross-check the findings, to increase confidence in the analysis.

The combination of tools including Pareto analysis, cause and effect diagrams, process flowcharts and work procedures has given a more in-depth understanding of the production system and made it easier to determine the most appropriate solutions to correct the problem.

2.6. Ethical Considerations

The research was conducted according to ethical principles. All data used in the study was handled with the utmost care of anonymity and integrity, and in accordance with the internal regulations of the companies. The researchers invited experts to participate voluntarily, and all information collected was used solely for research purposes. It was ensured that the results were presented truthfully and without distortion.

3. Literature Review

The literature related to textile quality assurance is reviewed based on the techniques employed for quality control, defect detection and process improvement.

3.1. Statistical Quality Control Methods

Statistical techniques have been employed over many years in textile industry to monitor and analyze variability and defects which occur during production. Over the recent years Statistical Process Control (SPC) methodologies have been introduced in order to govern and correct variations at optimal level. It has been practiced widely along with analytical diagnostic techniques such as Root Cause Analysis (RCA) in order to ensure reliability and product quality (Hwang et al., 2021) (Malek et al., 2017).

Miró showed that by introducing control charts and analyzing the process capability the textile nonwoven productions could be enhanced (Miro, 2008). Furthermore, by implementing Six Sigma methodologies to minimize the process variations, the overall performances of textile industries would increase, as showed by Dubrovski and Brezočnik (Dubrovski and Brezočnik ,2012).

Statistical techniques have also been carried out and explored within garment manufacturing systems to maximize the productivity in this sector and also to minimize the amount of defective products created, as showed by Ioan and Dorina (Ioan and Dorina, 2018). Besides this, a great number of other researches have explored statistical techniques in understanding complex structure of different type of textile surfaces and materials. As showed by Bui and Apley the development of statistical monitoring technique for stochastic textured surfaces would largely increase the accuracy in detecting defects in a large amount of textures represented by textile materials (Bui and Apley , 2017) .

Recently, Xu and Zhang proposed a statistical decision-support methods such as Analytic Hierarchy Process (AHP) sampling model in order to further enhance the detection rate in the defect inspection in quality inspection systems (Xu and Zhang, 2024).

3.2. Artificial Intelligence and Machine Learning Approaches As part of the advancement in the field of textiles, researchers have been working on exploring the potential of artificial intelligence (AI) and machine learning in textile sector. They have worked on various techniques for fabric inspection and defect detection in the fabrics. They came up with machine learning classifiers for fabric defect detection. They claimed that the automated system provided much higher productivity than the manual inspection. They further claimed that their proposed technique provided higher defect detection accuracy than the traditional methods. In another study, researchers proposed hybrid neural network model for yarn quality prediction. They claimed that the proposed model helped in controlling the spinning process parameters. They further claimed that the proposed model was superior to the traditional models. In a recent study, researchers used advanced artificial intelligence (AI) techniques for quality monitoring systems. They proposed an intelligent system that was able to detect the defects in real time during the textile production process. They further claimed that their proposed system was able to increase the productivity of the textile production line. In another study, researchers used machine learning techniques for supporting the predictive quality control and process and process optimization. In addition to the above studies, researchers have been working on using machine learning techniques for classifying the textile materials and determining the structural and mechanical properties of the materials. In a recent study, researchers proposed a new mechanical-based classification approach to identify the type of textile material and evaluate the quality characteristics of the material. They further claimed that the proposed method had many advantages and it was able to classify the materials with much higher accuracy than the existing methods. Overall, the intelligent systems that have been proposed in the recent studies have shown promising results in terms of their accuracy, speed and automation capabilities. Hence, they can be highly integrated with the modern textile manufacturing platforms.

3.3. Automated Inspection and Vision-Based Systems

Abstract Automated inspection systems employing image processing and computer vision techniques have become indispensable for assessing the quality of textiles to ensure that defective products are removed from the production line. Sari-Sarraf and Goddard pioneered work in vision-based fabric inspection employing systems that could be fixed on weaving machines to automatically detect faults and save time. Subsequent studies in the field of image processing employed varied techniques to carry out fault detection. For instance, Akbar et al. employed statistical filters and decision tree classifier for effective evaluation of faults in the textile fabrics (Akbar et al., 2013). Ibarra Picó et al. also worked on evaluation of textile fabrics using different texture analysis techniques and the results of their work showed efficient detection of surface anomalies in the fabrics (Picó et al, 2001). Objective assessment of the tactile properties as well as the visual appeal of textiles can also be carried out using instrumental methods. Wang worked on instrumental assessment of fabric hand quality. It evaluates the physical properties of the fabric that constitute the fabric hand quality of a textile product (Wang, 2016). Another study worked towards a comprehensive apparel quality control procedure by integrating inspection techniques along with the applicable standard test procedures (Keist, 2015). Hence, the role of automation in textiles using image processing and computer vision techniques is highly reliable.

3.4. Quality Management and Continuous Improvement Approaches

Many studies investigated the role of quality management systems at the manufacturing level and also the impact of organisational-level factors on textile production performance. Furthermore, an effective application of Total Quality Management (TQM) in organisations involves the participation of all members. Some of the recent studies also confirm the importance of integrating quality into all stages of textile production. For example, according to Gersak (2002), quality should be considered in all production phases. It was confirmed by Oliveira et al. (2016) that quality management practices have a significant and positive impact on the competitiveness and sustainability of textile firms. Moreover, the quality assurance in the education and skills development in the textile and fashion sector is another important topic.

It is important to train new generations to think with a quality perspective. For this reason, the Lean quality approaches are also considered to be of great relevance in the textile industry. Sao examined the implementation of Lean and quality management methods on children's apparel production to reduce accidents and defects (Sao, 2026). Supply chain quality management was also proved to be important for the improvement of textile manufacturing. Rhouma et al. (2025) investigated the most influential factors in textile supply chains that impact the performance and competitiveness of textile manufacturers.

3.5. Digital Technologies and Data-Driven Quality Systems

Da Cruz, B. C. S., Spyridis, N. and Panus, O. explored new applications of digital technologies to assure textile quality. According to them, digital product passports and artificial intelligence-based (AI) sorting systems may enhance the transparency and traceability in textile production systems. Recently, Da Cruz et al. (2024) pointed out the tremendous role of digital traceability systems in promoting sustainability and enhancing transparency in the textile supply chain.

Similarly, Spyridis et al. (2024) developed an AI-based sorting system to assist in better classification and recycling of textiles. Other applications of digital technologies in textiles include data quality assessment, sorting systems, digital traceability, fashion e-commerce and artificial intelligence for textile manufacturing.

Wijayono and Galih investigated data quality assessment frameworks that provide useful information to support textile manufacturers' decisions. Hussain introduced a Simple Additive Model based Learning – Quality Control (SAML-QC) framework for colour quality control in textile printing using parameters of textile printing machine that can assist in monitoring the printing process accurately.

Also, evaluation of fused textile composites and multilayer fabric structures using new test methods, was studied by Sudhakar and Renjini. The above digital systems can facilitate real-time monitoring and data analysis, while predicting the future performance of textile products to enhance the productivity of textile manufacturers.

3.6. Research Gap
While many studies have focused on textile quality control using statistical techniques, artificial intelligence and machine vision, there are many restrictions and research gaps that need to be explored further.
Firstly, a large number of studies focus on isolated stages of the textile production process (for example, fabric inspection or yarn quality prediction) and do not take into account the sequential nature of such a process. Secondly, the literature on the topic often focuses on the technological aspects and does not refer to the organizational aspects and production practices that are present in subcontracting production networks.
There is little information available on quality assurance in weaving plants that are part of large-scale production networks, consisting of several workplaces and subcontractors, where tasks and operations are carried out under different conditions of technology, labor skills and operational procedures.
To meet these requirements, it is necessary to set up an integrated quality diagnostic framework based on statistical analysis, defect classification, root cause analysis and control of production processes that are in line with the specific context of textile subcontracting platforms.
3.7. Contribution of the Study (Practical Contribution)
This study provides several practical contributions for textile manufacturing platforms:
• Identification of the most critical defects occurring during textile production.
- Statistical methods like Pareto analysis may be applied to help in prioritizing the number of quality issues that need to be addressed.
• Development of structured inspection procedures for subcontracting workshops.
• Possible solutions for action intended to minimize fabric losses and second-choice products.
• Improvement of quality monitoring practices across different stages of production.
Textile companies can improve their performances on efficiency and economic impact of non-quality by means of these contributions.
3.8. Applied Contribution – Conceptual Framework (Integrated Model)
This research proposes an **integrated quality assurance framework** combining several complementary components:

A. **Quality Diagnosis**
  - Analysis of workshop performance
  - Identification of defects and losses

B. **Statistical Analysis Tools**
  - Pareto charts
  - Defect distribution analysis
  - Quality performance indicators

C. **Root Cause Analysis**
  - Cause-and-effect diagrams
  - Process evaluation

D. **Operational Control Procedures**
  - Inspector procedures
  - Supplier quality specifications

E. **Continuous Improvement**
  - Corrective and preventive actions
  - Monitoring of quality indicators

This integrated model allows textile platforms to implement a systematic quality improvement approach covering the entire production system.
4. The Results
4.1. Importance of the quality diagnostic
The quality diagnosis aims to provide the quality steering committee with the necessary information to develop an effective and accepted quality strategy. This process takes into account the current state of achievements, existing operational modes, and the main gaps relative to quality requirements. The objectives of the quality diagnosis are therefore multiple: first, it identifies crucial information to guide the quality strategy; second, it highlights opportunities for improvement as well as dysfunctions related to quality. Additionally, this diagnosis proposes action plans and programs tailored to the chosen strategy and observed practices. Finally, it defines the priorities and implementation modalities for a quality approach. In summary, the quality diagnosis serves as an essential preliminary step before any quality actions. This study will focus on analyzing the various parameters related to quality organization within the company, specifically through the examination of workshops and controllers.
4.2. Case studies for the workshops
4.2.1. Exceeding consumption

While it may seem practical to provide contractors with a larger quantity of fabric than initially planned to compensate for potential defects and minimize production delays, a more effective strategy is to monitor fabric usage at the workshop level.

This is particularly important considering that raw materials account for approximately 50% of the product's total cost. Figure 1 illustrates the percentage of fabric overconsumption for each workshop.

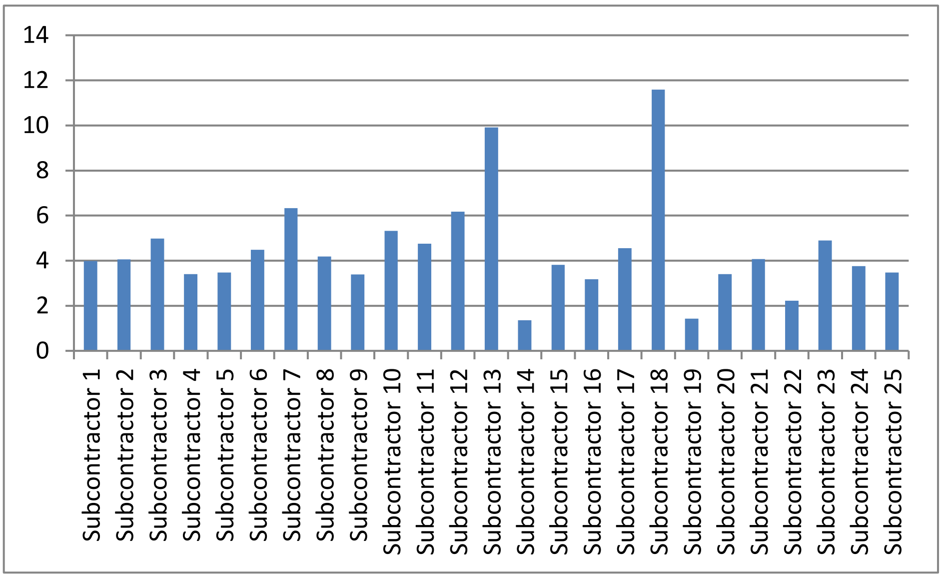

Figure 1. Overconsumption percentage per workshop

According to figure 1,the average overconsumption percentage per workshop is 4.34%. Workshops that exceed this threshold indicate a weakness for the company, while those with lower percentages are considered strengths. The formula for calculating overconsumption is presented in equation 1:

$$\%\ \mathbf{Overconsumption} = \frac{\mathbf{Defective\ quantity\ of\ fabric}}{\mathbf{Total\ quantity\ of\ fabric\ delivered\ to\ the\ subcontractors}} \times \mathbf{100} \qquad \mathbf{(1)}$$

Where:

- Defective quantity of fabric refers to the footage of defective fabric.

Among the three workshops C, Delta, and Excellence Style stands out with a notably high overconsumption percentage of 12%, significantly above the average.

4.2.2. Losses in quilting operations

One of the primary sources of material loss during quilting is the presence of defects in the fabric rolls. Monitoring the percentage of loss in the quilting process is essential for evaluating the quality of work delivered by the contractors. Figure 2 presents the distribution of losses in the quilting operation across the different workshops.

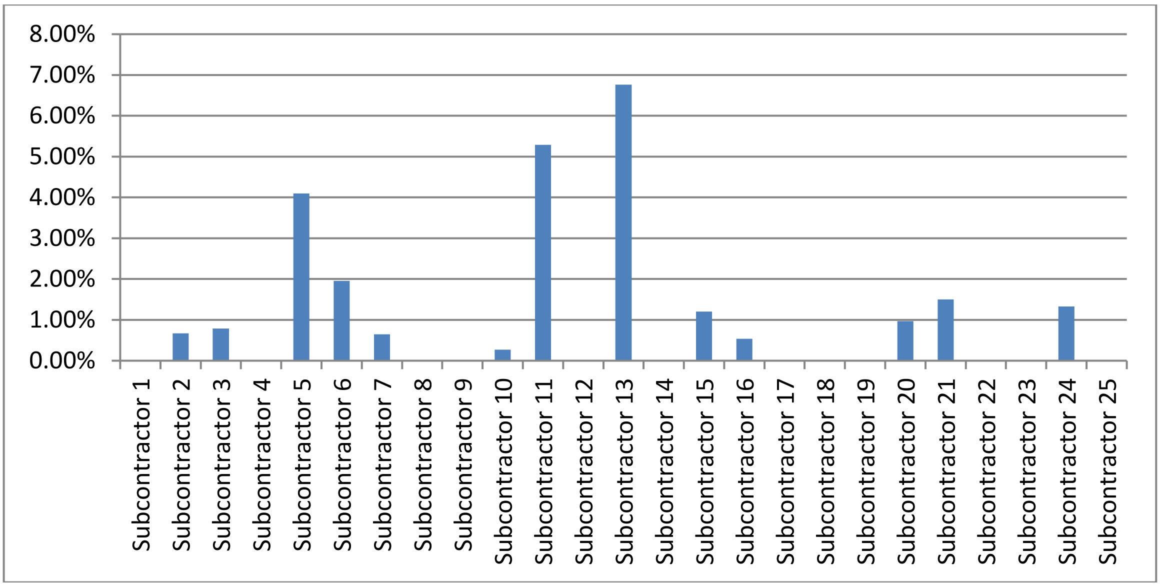

Figure 2. Distribution of losses in quilting operation per workshop

The percentage of loss in quiltinis presented in equation 2:

$$\% \textbf{ Loss in quiltin} = \frac{\textbf{Actual consumption} - \textbf{Planned consumption}}{\textbf{Planned consumption}} \times \mathbf{100} \qquad \textbf{(2)}$$

Where:

- **Actual consumption**: the actual fabric consumption by the workshop
- **Planned consumption**: the planned fabric consumption

From the graph, it can be observed that the percentage of loss during quilting is high for the workshops: NS Conf, Nouvelle Génération, and Meghatex. For example, the loss during quilting for NS Conf is 22%. Therefore, these workshops require more rigorous monitoring during the quilting operation.

4.2.3. Percentage of first choice

The percentage of first choice materials is an important factor when deciding which workshop to order to. For example it may be preferential to order from customers who have very tight tolerances if a factory has a high percentage of first grade materials. This will help to ensure that the product and service that the customer receives is of a high standard. Figure 3 shows the percentage of first choice materials for each of the factories.

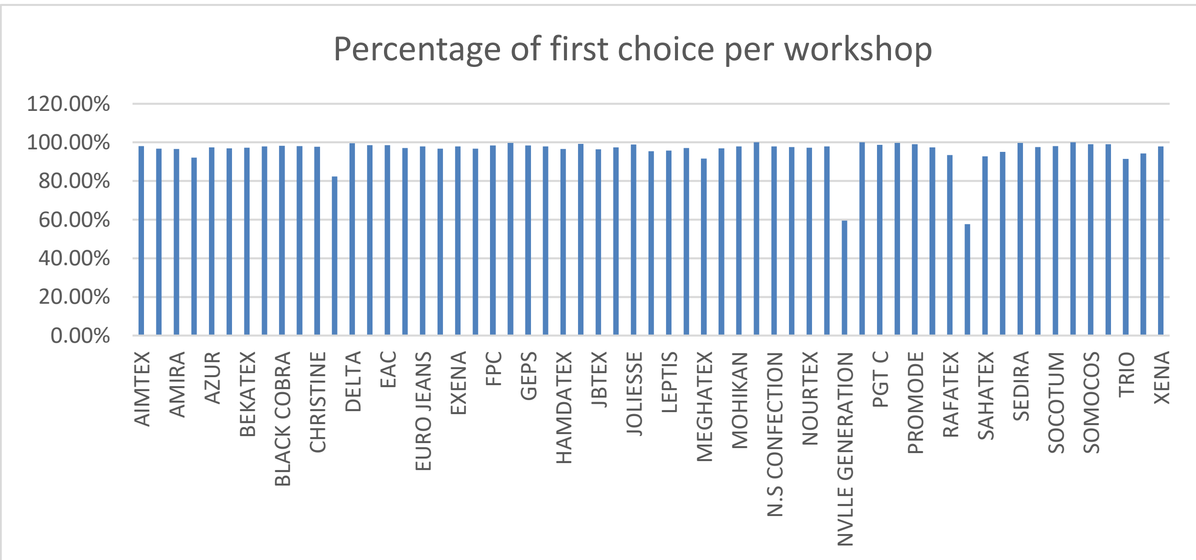

Figure 3. Percentage of first choice per workshop

The percentage of the first choice was calculated according to the following formula :

Percentage of first choice = (first choice pieces / cut pieces) * 100 (3)

Based on the obtained values, the workshops can be ranked in order of priority in order to minimize quality problems and ensure a better allocation of orders among them. According to the figure, the average first-quality percentage is estimated at 97.34%. However, the graph highlights that two workshops have a relatively low first-quality percentage, which makes them weak points within the company. In this context, implementing targeted corrective actions is necessary to improve the required quality level in these two workshops. Furthermore, analyzing the second-quality percentage for these workshops, along with identifying its root causes, is essential to effectively guide corrective actions and enhance overall performance.

4.2.4. Percentage of second choice

2nd choice products are bad products for us. So we are interested to see the weaknesses of our production and therefore the second choice rates per workshop give us some very useful information. The second choice % per workshop is given in the following table :

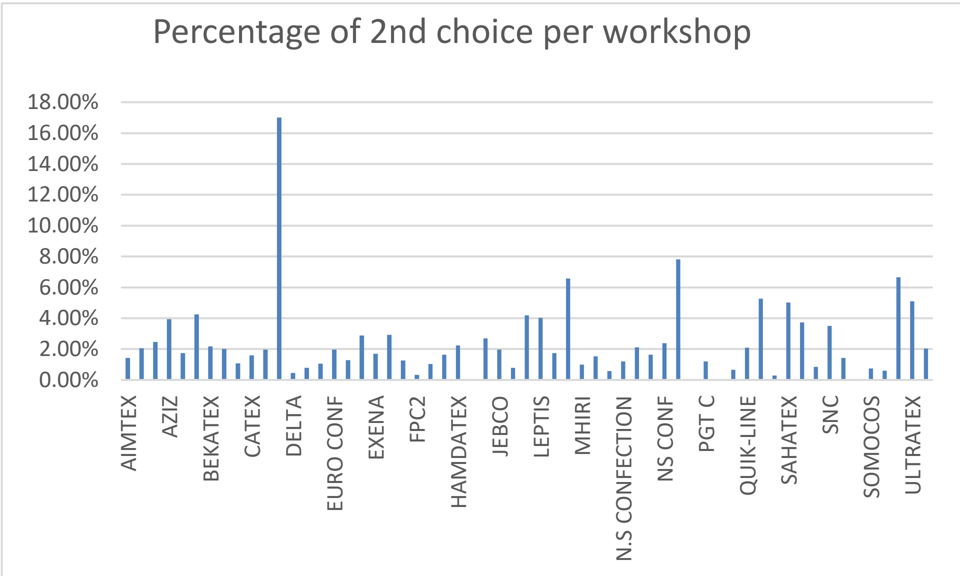

Figure 4. Percentage of 2nd choice per workshop

The percentage of the second choice was calculated according to the following formula :

Percentage of second-choice pieces = (number of second-choice pieces / number of pieces cut) * 100 (4)

- The average percentage of second-grade materials retained is 1.7%. This value seems low, but when considering the company's annual production rate, it reveals an undesirable situation.
- Lowering the average second-grade rate means maintaining the quality level for workshops with a high first-grade percentage and reducing second-grade values below 1.7%.
- The distribution above shows a high second-grade rate for the workshop: CTV: 17%.
- This rate requires the Platform to change its policy towards its subcontractors.

4.2.5. Repair percentage

The repair rate per workshop informs the quality manager about the level of quality required within each workshop. The repair rate was calculated according to the equation 5:

Repair rate = (total repair / cut parts)*100 (5)

The distribution of the repair rate per workshop is presented in figure 5:

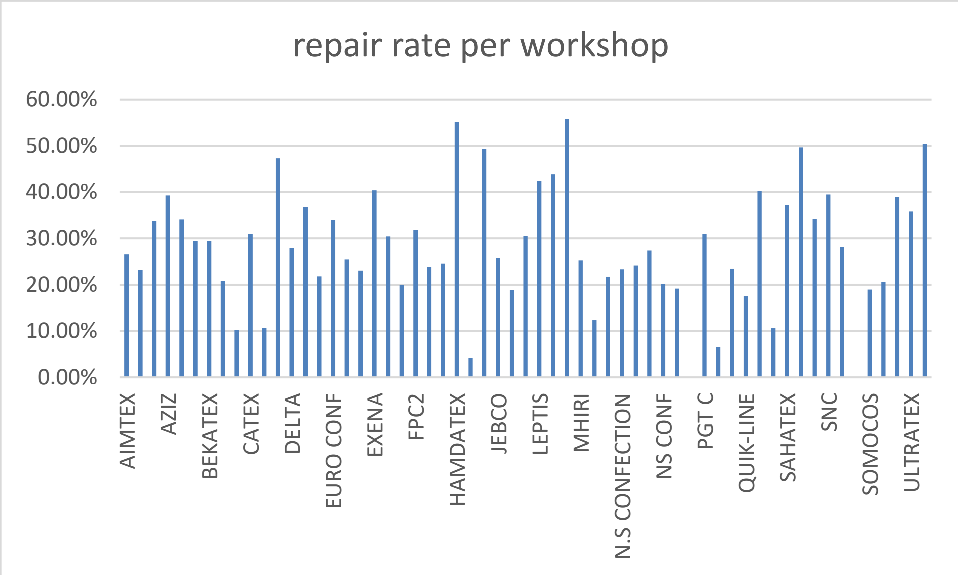

Figure 5. Repair rate distribution per workshop

The average repair rate per workshop is 25.40%. Any workshop with a rate exceeding 25.40% can be considered to have a problem. We note the presence of values between 50% and 60%, as is the case for Hamdatex and Meghatex. These two workshops have a repair rate twice the average. Reducing the average repair rate means first reducing the repair rate in workshops with above-average rates. This type of graph is useful for better maintaining quality across the different workshops. For those with high percentages, it is necessary to more closely monitor the subcontractors during production and explain all product quality criteria.
This section focused on the study of the workshops. These monitoring activities allow the quality manager at the platform to understand the required quality level better, identify problem areas, and implement effective solutions. Furthermore, this study enabled us to classify the workshops according to the parameters already described.

4.3. Case studies for controllers

4.3.1.Study of second choice distribution

4.3.1.1. Second choice fabric

To better understand the defects in Second Choice Fabric, we use a graphical analysis presented in the following Pareto diagram:

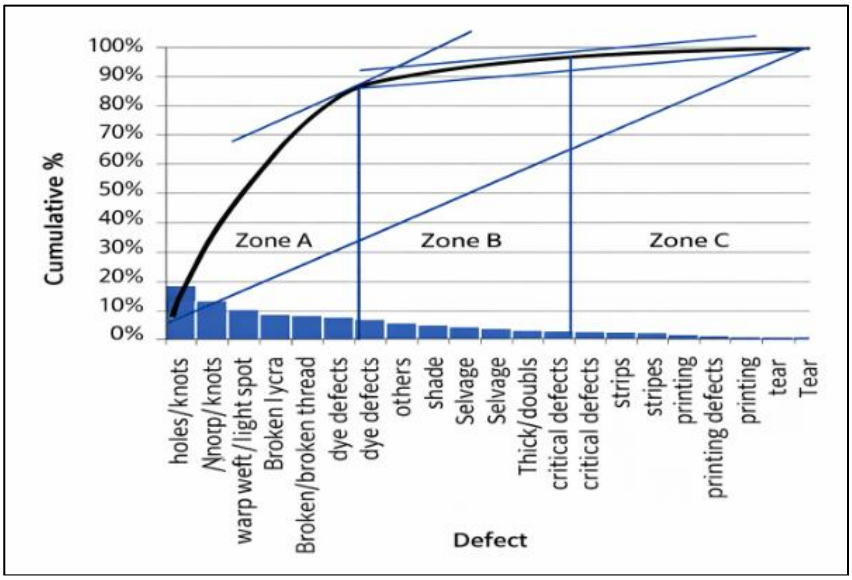

Figure 6. Pareto diagram of second choice fabric

According to the Pareto diagram, we can see that the following four defects—holes/nodes, machine stops/clearing, broken lycra, and missing thread—are the most frequent. Therefore, a corrective action must be implemented for this group of defects.

4.3.1.2. Second choices observed during manufacturing

The occurrence of defects during product assembly is directly related to the number of basic assembly operations. Some defects can be corrected, particularly if they are identified early in the process. However, more serious defects, or those detected too late, may result in product rejection, downgrading the item to second-choice status. To better understand the factors leading to product loss, we conducted a detailed analysis of the most frequent defects. The following Pareto chart (Figure 7) illustrates the distribution of defects in the garment production process, highlighting those that have the greatest impact on quality and product rejection.

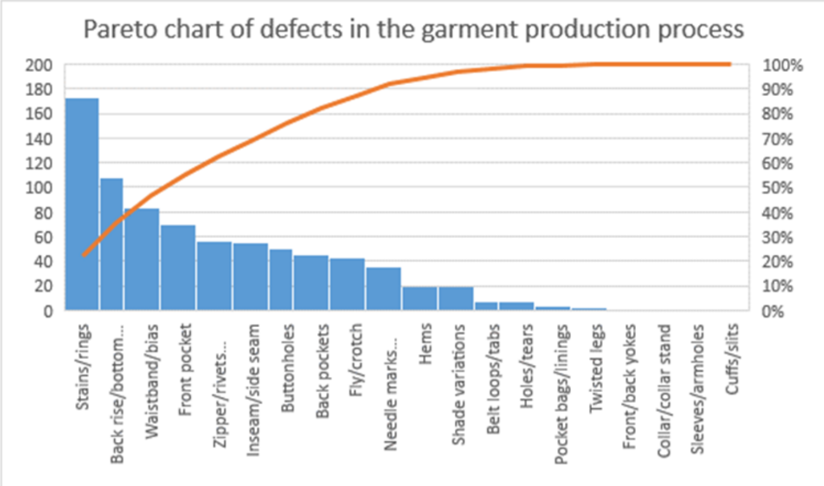

Figure 7. Pareto chart of defects in the garment production process

According to the Pareto chart, the first eight defects account for 80% of the total percentage of second-quality garments. Therefore, reducing the percentage of second-quality garments boils down to finding solutions to minimize these defects. Determining the actual causes of these defects is the subject of the following section, using cause-and-effect diagrams.

4.3.1.3. Second choices observed during washing

After many trials I came to the conclusion that the design of the washing cycle is crucial to quality of the end product, because it is at this stage that some hidden design faults or non-compliances to specified design tolerances become apparent. A non-optimized washing cycle will always result in numerous defects, usually due to non-compliance to certain aspects of the process, including; incorrect bath settings, inadequate drum cleanliness or a failure to operate within the defined process parameters. Here is a graphical analysis of the washing process depicted in a Pareto chart.

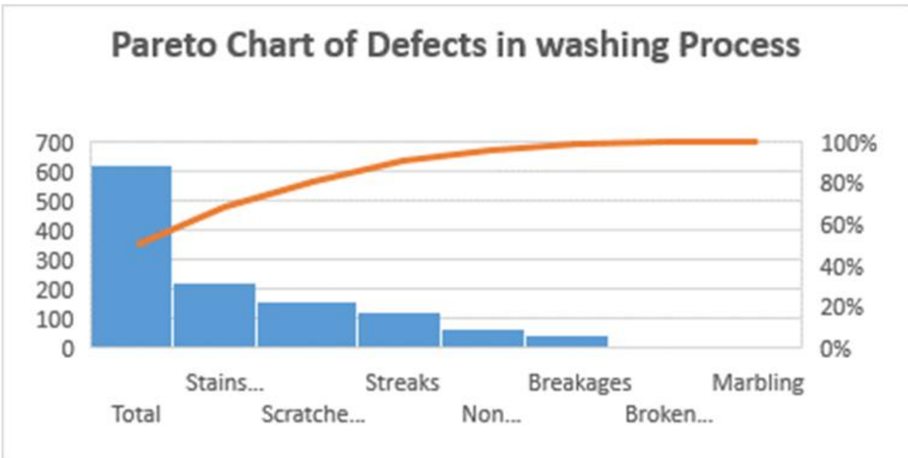

Figure 8. Pareto chart of defects in washing process

According to the Pareto chart above, stains/dirt, scuffs/holes, and scratches are the major defects during the washing process, thus resulting in the classification of products as second-choice. Eliminating the causes of these defects leads us to reduce the percentage of second-choice products. Such corrective action should aim to eliminate the causes of these defects first, and then address the less frequent defects.

4.3.1.4. Second choice at the special processing level

The aim of special treatments is to give products a particular effect, but if they are aggressive, they can destroy products that will then be classified as second-rate.
Therefore, we use a graphical analysis represented by the following Pareto chart:

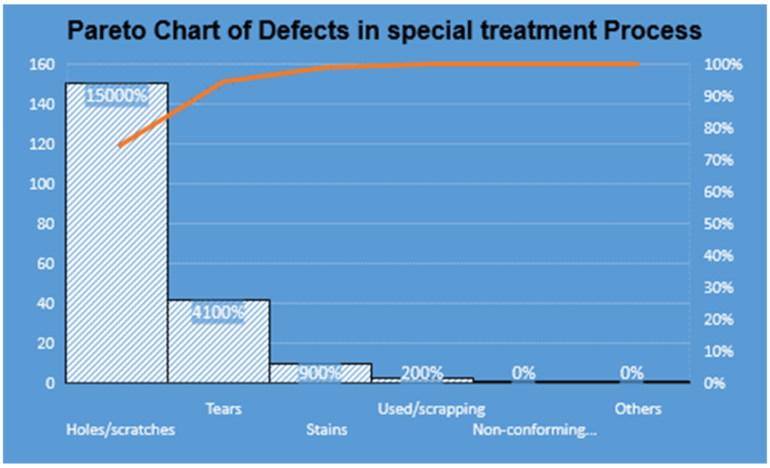

Figure 9. Pareto chart of defects in special treatment process

According to the Pareto chart, the defect—hole/scratch—accounts for 80% of the effect. Therefore, to minimize the rate of second-choice treatments, we must first identify the causes of this defect.

4.3.2. Study of rework

It's true that these kinds of defects are repairable, but reducing the rework rate allows the company to save time, speed up shipping, and therefore maintain customer loyalty. We therefore use a graphical analysis represented in figure 10:

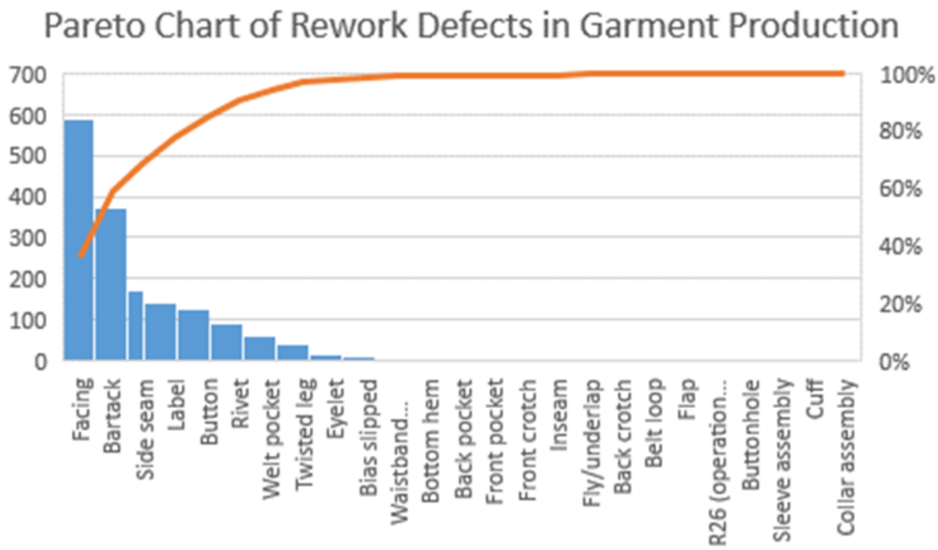

Figure 10. Pareto chart of rework defects in garment production

We can see from the Pareto diagram that the most frequent defects are at the level of the following operations: waistband assembly, bottom hem, back pocket and front pocket, front crotch, crotch, fly, back crotch, belt loop and flap.

4.3.3. Study of stain removal

Throughout the production cycle, the material is in contact with the machines; therefore, the cleanliness of the machines and the work environment guarantees a clean product.

We thus use a graphical study represented in figure 11:

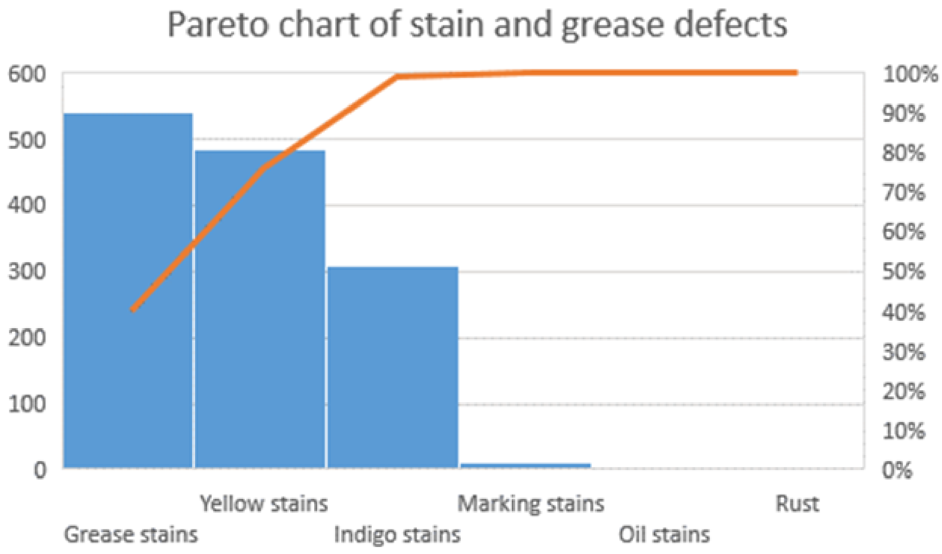

Figure 11. Pareto chart of stain and grease defects

The Pareto chart shows that oil and grease stains constitute the area of most frequent causes. Therefore, reducing the defect rate means decreasing the rate of oil and grease stains by identifying their root causes.
Grease and yellow stains are defects that should be addressed secondarily.
According to the curves of the Pareto charts, defects can be classified into three zones:

- Zone A: This zone represents the majority of causes and must be addressed as a priority. Defects in this zone require urgent intervention.
- Zone B: This zone includes causes that will be addressed secondarily.
- Zone C: This is the zone of defects with the lowest percentage of defective parts.

To reduce this defect rate, we must first identify the origins and then implement the corresponding solutions.

4.4. Action plans

4.4.1. Inspector procedure

a. Objective

This procedure aims to provide concise control advice during missions in subcontracting workshops.

b. Scope of application

This procedure is intended for Company inspectors or any other person mandated by the compay assigned to control productions in subcontracting workshops.

c. Arrival at a new workshop

- Observe the welcome upon your arrival. The behavior (politeness, availability, etc.) of the owner, managers, etc., towards you determines the respect they have for the company.
- Observe the cleanliness of the premises, machines, and workers (e.g., eating at the workstation).
- Observe the work pace (machine noise), the behavior of the workers—are they diligent or distracted? The discipline within the workshop.
- Observe the material resources:
  - Conduct a quick assessment of the number of machines by category.
  - Look at the types of equipment or attachments at the stations. Are they present? Are they being used correctly?

○ Are spare parts well managed and available in sufficient quantities to handle any minor breakdowns?

After the observations, summarize the findings and report to the site manager.

d. Preliminary control

- Ensure that supplies received on site match the needs outlined in the technical file.
- Check the quality of the cutting:
  - Elimination of defects as specified by the Company specifications.
  - Check for end losses during padding.

- Check the tensions applied to the fabric during unfolding and the proper alignment of the edges.
- o Check the organization of packaging and any type of marking.

e. In-Process control

At each workstation, verify the following elements:

- Cleanliness of the machine and its environment (oil leaks, greasy dust, no lunch basket nearby, etc.).
- Machine settings: Number of stitches, thread tension, presser foot pressure, proper differential settings, etc.
- Compliance with stitching values and notches.
- Size and condition (pointing) of the needles.
- Additional guides or markers that can facilitate production.

f. Final control

- Check the overall appearance of the product. The uniformity of the number of stitches, flat seams, etc.
- On the reverse side, check the assemblies, missing stitches, fraying, uncut threads, etc.
- On the front side, measure the following: waistband width, fly openings, belt loop openings, pocket entries; depending on the type of garment, measure everything indicated in the file, such as cord length.
- Finally, measure the garment to verify compliance.
- Complete the documents and report to the line manager and the site manager.

g. Shipping

- Check the numbers of cut quantities, launched, and finished at each stage.
- Ensure that the quantity of first-choice items shipped plus that of second-choice items corresponds to this figure.
- Check by sampling that there are no mixes in the packages.

h. Remarks and advice

- Hold line managers accountable for the company quality.
- A defect identified by our inspector must be corrected by the worker in the presence of their supervisor.
- If a recurrence occurs, speak with the supervisor and inform them that Company can no longer accept the reproduction of the defect without informing the factory management to consider sanctions (see the site manager).
- The Company inspector or any person mandated by Company is not responsible for the quality of the site or the proper progress of productions. This responsibility lies with the site.
- The Company inspector or any person mandated by Company serves only as a guide, helper, and advisor.
- If the instructions given by the Company inspector or any person mandated by Company are not followed, they must report to their superior.

4.4.2. Supplier fabric specifications procedure

a. Objectives

The quality of a fabric can be viewed in two different ways:

- The quality from the perspective of the supplier or finisher.
- The quality from the perspective of the manufacturer.

Experience shows that differences can exist between the two. For the past 15 years, the company has established a correlation between the visual inspection of a batch of fabric and the consequences of defects on the finished product, while adhering to all professional quality construction rules during the padding, cutting, assembly, and finishing processes of a textile item. The control criteria applied by the company form the necessary acceptance basis for suppliers wishing to work with the group.

Company suppliers must certify in writing that they:

- Are well aware of the company's specifications as they have read them.
- Accept the rules defining the framework of their relationship with the company.

These two points will be confirmed by the "partner commitment" signed by both parties involved.

b. Fabric piece control

Each the company fabric supplier is required to ensure that all delivered pieces have undergone careful final inspection. Suppliers are asked to use the the company method or another method approved by the company that allows them to achieve the quality level desired by the company.

- *Verification method for incoming pieces*

The verification method consists of assigning a loss measurement to each defect. This measurement is flat-rate and corresponds to the fabric loss observed by the company after 15 years of experience during the padding and cutting operations of the fabric. These defects are classified into three categories as presented in table 1:

Table 1.Classification of defects

Category	Length L of the defect (warp or weft)	Flat-rate loss
1	L < 5 cm	0.25 m
2	5 cm < L < 45 cm	0.5 m
3	L > 45 cm	1 m

The sampling of pieces follows a statistical law based on the delivered footage.

- *Specific criteria*

- No more than one meter of flat-rate loss will be given per linear meter, regardless of the number of defects in that meter.
- There can be no category 3 defects in the first and last meter of a piece.
- Any defect, regardless of its nature, is penalized based on its size. This criterion alone will visually affect the final quality of the manufactured item.
- A category 3 defect longer than one meter may result in either considering a defective fabric measurement equal to the length of the defect or the downgrading of the entire piece.

Remarks:

- A reported defect remains a defect. Proper marking of defects by the supplier will be given special attention by the company.
- All defects must be marked with a color code on the selvage at the height of the defect. Additionally, the company requests that the supplier highlight each defect with an ultraviolet marker directly on the fabric.
- This operation allows for shared responsibility between the fabric supplier and the manufacturing unit in case of defective items due to fabric defects. The use of ultraviolet ink ensures traceability even after washing treatment.
- For any defect marked and noted with UV by the fabric supplier but not eliminated by the manufacturing unit at the cutting stage, the cost of non-quality will be borne by the manufacturing unit. Conversely, if items are downgraded due to fabric defects and these are not identifiable with a UV mark, then the cost of non-quality related to these issues will be borne by the fabric supplier.
- The acceptability threshold for second-choice pants with fabric defects after the company's manufacturing is set at 1%. The quantity of second-choice pants exceeding this 1% rate will be charged according to the responsibilities determined by the aforementioned method, either to the manufacturing unit, the fabric supplier, or the washing process.
- Any billed item will be calculated based on the company's industrial cost price.

Accounting for defects

Each defect is assigned a flat-rate fabric loss. The defective footage corresponds to the sum of the losses calculated. The percentage of fabric lost is deduced in relation to the footage inspected. The statistical sampling of the inspected pieces from the delivered batch is representative of the batch, and the calculated loss percentage applies to the entire batch after a second sampling confirming the first or a 100% inspection of the delivery. the company commits to accepting any request from the supplier to verify the application of the control method or to carry out a counter-inspection in case of dispute.

- Acceptable quality levels:

The acceptable quality level (AQL) is set at 4%, the upper limit of the percentage of defective fabric calculated in the batch. Two situations are distinguished:

- If the calculated percentage of defective fabric is less than or equal to 4%, the batch is accepted.
- If the calculated percentage of defective fabric exceeds 4%, the batch is declared contentious. This delivery may either be rejected or accepted with a penalty for the supplier.
- The maximum defect rate accepted per piece is set at 6.5%. Any piece with a calculated percentage greater than 6.5% will either be rejected or accepted with a penalty for the supplier.

Special cases: Immediate rejection of pieces:

- Variation in shade within the same roll.
- Width less than the minimum usable width guaranteed by the supplier.
- Irregularity of the width along a roll.
- Repetitive defects along the length of the roll.
- Shrinkage difference greater than 2% compared to the technical sheet.

The quality department autonomously decides on the non-acceptance of a delivery that does not meet quality requirements. If it appears that more than 5% of the delivery is rejected for quality reasons, the entire delivery may be refused, with the possibility of canceling the order, resulting in billing for all costs and loss of profit.

c. Technical characteristics of the fabric

- *Grammage (Weight/m²)*

- All deliveries are subject to weight control according to ISO 3801.

- Any delivery with a deviation of more than 5% from the technical sheet may result in order cancellation or additional charges.

- *Usable width*

The usable width must be at least equal to the minimum usable width indicated on the technical sheet across the entire roll. Therefore, the tolerance for width has a lower limit of 0 cm and an upper limit of 3 cm. In the case of pieces with a usable width less than the minimum usable width indicated on the quality sheet, these pieces will either be:

- Returned to the supplier.
- Accepted with the supplier bearing the costs incurred for the study and layout of new placements, as well as the fabric loss. The fees amount to 200 Euros per model to be traced, plus the corresponding amount for the footage lost due to this width variation.

- *Length of pieces*

The length of pieces is controlled during the passage of the fabric through the inspection machine. The device of the inspection machine allows for the rolling out of the rolls without tension and records the footage on a counter.

- *Manufacturing standard*

The manufacturing standard is the sample cut sent by the supplier for the studied and approved collection. This sample will be considered the standard for color, touch, and texture for the entire lifespan of the product. The supplier indicates whether this sample cut comes from industrial production or if it is a special request from the company.

- *Color standard*

Each industrial production delivered to the company is compared with the manufacturing standard under a standardized light cabinet illuminated by D65. Two shades are accepted in the total quantity ordered and delivered, with the overall deviation observed between the sample type and the delivery, and between two shades in a delivery, not being less than 1.2 according to the CMC method. For denim fabrics, only two shades at most are accepted and must be based on the same shade of Indigo.

Depending on the fabrics, fabric samples taken by the supplier at the beginning and end of each piece delivered to the company may accompany the delivery. Color deviations are classified into numbered homogeneous batches. For denim fabrics, the company requests that the supplier provide a constructed and stone-washed patchwork along with samples taken from the delivery. The overall observed deviation of shades must not be less than a rating of 4/5 on the gray scale. The maximum accepted shades must be within the same shade of Indigo.

- *Color uniformity*

The shade must be homogeneous throughout the length and width of the piece. Likewise, a batch of the same shade, defined by a dye lot number, must consist solely of homogeneous pieces. In the case of a shade deviation in a piece or within a lot, non-compliant or out-of-tolerance fabric or manufactured pieces will be rejected.

- *Dimensional stability*

For dimensional stability testing, the company performs industrial washes to replicate the washing conditions of trousers manufactured under industrial finishing conditions. For items not requiring this finishing, only a home wash is performed.

the company uses three types of washes and one dyeing method, depending on the fabric type. Suppliers can contact THE COMPANY for precise washing recipes. The Company's industrial washes and dyeing test methods are summarized in Table 2:

Table 2. Industrial washes and dyeing test methods

Type of fabric	Type of washing	Washing temperature (°C)	Type of drying	Drying temperature (°C)
Ready to dye	Dyeing	98*	Tumbler drying	85*
Denim	Stone	60	Tumbler drying	85*
Other fabrics	Washing (detergent)	60	Tumbler drying	85*
Other fabrics	Washing (softener)	35	Tumbler drying	85*

(*) : Except for technical constraints related to the fabric

- *Angular deviation*

The angular deviation is calculated using the method described below:

Methodology:

1. Take a one-meter length of fabric, taking care not to stretch the fabric or apply any mechanical tension.

2. Unravel the fabric strip until you find a thread running across the width from one selvage to the other. The edge of the strip thus created indicates the weft direction.
3. Draw a line AB approximately 50 cm from the edge of the fabric strip and parallel to it.
4. Draw a line CD parallel to the selvage of the fabric strip. Mark point E as the intersection of AB and CD.
5. Draw a perpendicular line EF to line CD passing through E. Place a point G on line EF, one meter from point E.
6. Draw a line parallel to the selvage and passing through point G. Mark point H as the intersection of this parallel line and line AB. The value X is equal to the distance in cm between points G and H. Calculate the quotient X/100 to obtain the angular deviation as a percentage.

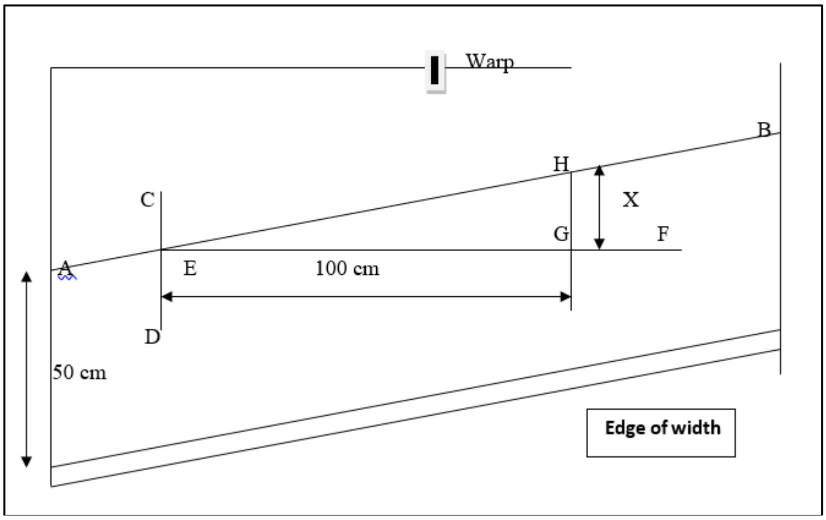

Figure 12 . Angular deviation

d. Fabric piece characteristics:
-Piece length

- A piece must be at least 40 meters long.
- A piece shorter than 100 meters can only contain one seam or cut.
- A cut must be at least 15 meters long.
- The lengths on either side of a cut must be uniform and have the same characteristics (width, shade, feel).
- The number of pieces with seams or cuts cannot exceed 20% of the delivered lot.

- Packaging of Pieces
The pieces are packaged in transparent, recyclable plastic packaging that is sealed at both ends.
The tubes used must be strong enough to withstand the winding of the fabric without being crushed. Tubes with an outside diameter of 50 mm and a cardboard thickness of 5 mm should be used.
- Part labels
For storage reasons, it is requested that the part labels be affixed to the circular face of the rolls. These labels contain the following information:

- Supplier reference
- Supplier color
- The company shirt reference and color
- Batch or production number
- Piece number
- Shade number
- Piece length
- Gross weight
- Net weight
- Actual measured width of the piece
- Number of cuts

e. Delivery
-Packing list
The delivery packing list includes the information indicated on the piece labels:

- The company shirt order number

- Supplier reference
- Supplier color
- Batch or production number
- Piece number
- Shade number (color swatch, special numbering…)
- Piece length
- Gross weight
- Net weight
- Actual width of the piece
- Number of cuts

This list accompanies the delivery. A copy is faxed to the company upon shipment of the goods by the supplier. The packing list must remain legible and accurate.
-Delivered Length
The delivered length is the length ordered:

- Plus or minus 5% for any order less than 1000 meters
- Plus or minus 3% for any order equal to or greater than 1000 meters and less than 5000 meters
- Plus or minus 2% for any order greater than or equal to 5000 meters

-Delivery
The requested delivery time is confirmed in the order. The delivery date provided by the supplier is the date the goods arrive at the site as specified by THE COMPANY in the order.
-Transport
Vertical transport of the pieces causes the fabric to ripple along the selvedges. The rolls must be transported horizontally on pallets under suitable transport conditions. The use of pallets does not apply to velvets. Any damaged piece or non-compliant transport will be noted on the delivery slip.

- the company may request compensation corresponding to the loss of fabric due to handling or transport conditions that have damaged the rolls (dirty pieces, torn or ripped fabric, etc.).
- the company undertakes to provide the supplier with a precise description of any damaged delivery, accompanied by samples or digital photographs transmitted electronically.
- If the company observes, before unloading, that the delivery is damaged or deemed unacceptable, and that this has been observed in previous deliveries and reported to the supplier, the company may immediately refuse the goods.
-

4.4.3. Supplier fabric specifications section: Purchase conditions

4.4.3.1. Sampling

Every order is subject to prior sampling. Deliveries of cuts less than or equal to 5 meters will be made free of charge by the supplier.

4.4.3.2. Order confirmation

When placing an order, the company confirms this order to the supplier via fax or email, specifying the desired quantities for each reference/color as well as the delivery time and location.
In return, the supplier confirms the feasibility of the order within the timeframe requested by the company. The supplier must include in their response the company's order number, the reference/color of the quality concerned, the footage, the price per meter, the confirmed delivery date, and location.

It is reminded that the company indicates the delivery location for the ordered goods on its purchase order. The supplier must take this location into account when confirming the delivery time.

4.4.3.3. Color Standards

4.4.3.3.1. Supplier Color Range

The Company takes the supplier's color board as the color standard. It informs the supplier of this choice. Without any contrary order from the supplier, the sample taken from the board becomes the definitive color standard.

4.4.2.3.2. Color Study

The Company may request a special color from the supplier. In this case, it provides a color sample to the supplier for them to conduct their study.

4.4.3.3.3. Compliance with Legislation

The supplier commits to strictly adhere to the legislation and regulations in force regarding fraud prevention and to take all necessary precautions to ensure that the fabrics and manufactured items delivered by them cannot, under any circumstances, be subject to copyright infringement or unfair competition for any reason. The supplier is obligated to mention the country of origin for each quality on the quality sheet, as well as on every shipping note and invoice.

If the supplier fails to mention the country of origin on the invoice/shipping note or through a separate written confirmation, the company will consider the goods as originating from a European country.

In this section, we aimed to establish four quality specifications, which include procedures and regulations that organize the work according to a well-defined operating mode.

4.4.4. Quality Manual and Work Instructions Standardization

In this section, we developed quality specification documents that rigorously describe the work procedures in accordance with execution standards, supported by photographs and detailed descriptions of each step.

These specification documents constitute a quality manual for the company. Indeed, each operator must have a copy of the adopted method in order to perform their work correctly.

4.4.4.1. Quality specifications: Trouser measurements

Table 3 presents the quality specifications for trouser measurements.

Figure 13. Waist Measurement

Positioning the Trousers:

Fasten the waistband button.

Align the front and back on the table.

Important: Do not pull at the waistband.

Take the measurement with the trousers laid flat.

Figure 14. Hip Measurement

1. Lay the trousers flat on the table.
2. Measure at the level of the fly according to the measurement chart (hip height).
3. Repeat the same for both sides (hip height).
4. Take the measurement based on these three points

1. Measure from above or below according to the instructions from the measurement chart, from the waistband to the cross seam.

Figure 15. Front Rise Measurement

Measure from above or below according to the instructions from the measurement chart, from the waistband to the midpoint between the two needles if the inseam is made by a machine arm.

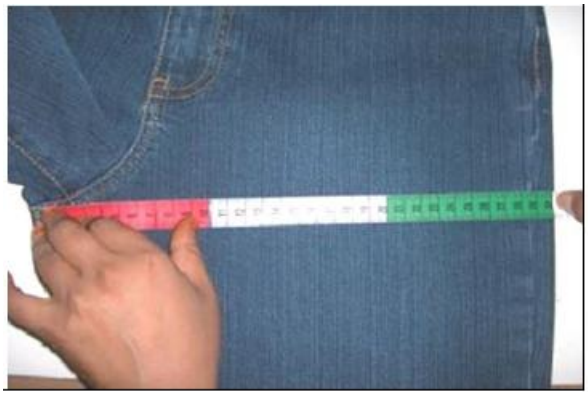

Figure 16. Thigh Measurement

1. Position the leg straight.
2. Ensure that you remain perpendicular to the grain line

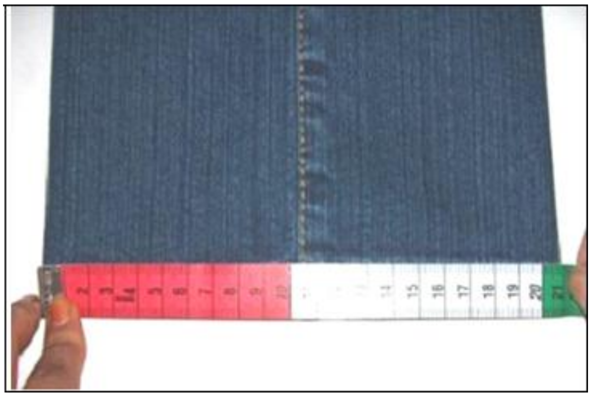

Figure 17. Hem Measurement

1. Fold the seam.
2. Measure at the level of the hem seam.

4.5. Results of applying actions plan
4.5.1. Evaluation of Rework Percentage

The evolution of rework percentage after applying action plan is presented as follows:

Table 3. Evolution of Rework Percentage

Month	% Garment Rework	% Fabric Rework	% Washing Rework	% Special Treatment Rework	% Total Rework
February	15.76%	6.00%	2.30%	1.59%	25.65%
March	14.39%	6.07%	1.17%	1.39%	23.01%
April	14.05%	5.82%	0.97%	1.08%	21.92%

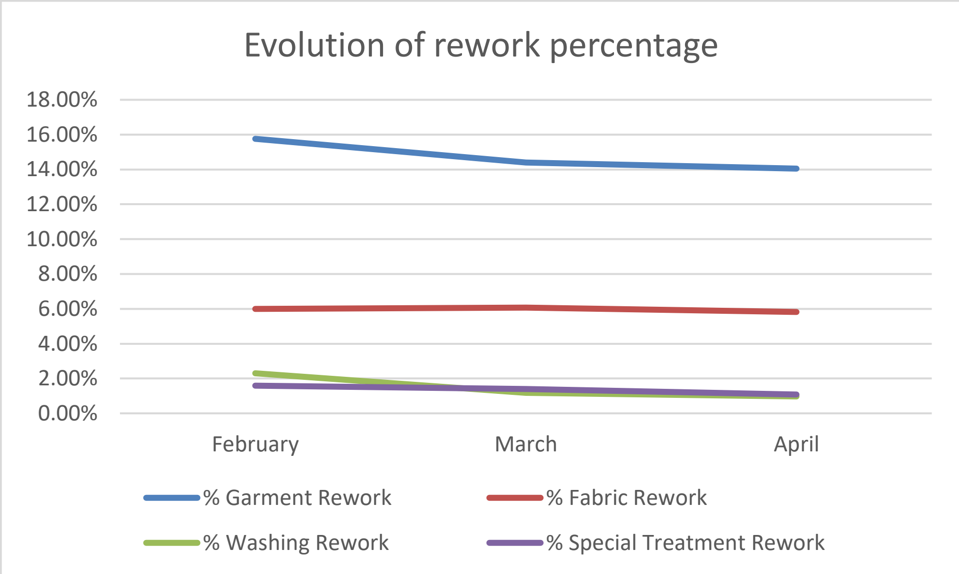

Figure 18. Evolution of Rework Percentage

This plot shows the percentage of items for which we need to rework the Garment, Fabric, during washing or after a Special Treatment across the months of February, March and April. The blue line shows the Garment Rework was actually very stable around 14/15% throughout the period. Fabric Rework is going down instead (8% in Feb, around 6% in Apr) and so is Washing Rework with relatively small oscillations going from about 7% to 6%. Special Treatment Rework is low and stable around 2/3%. Overall Fabric and Washing rework rates are coming down while the analysis of Garment Rework needs to continue in order to identify any area for improvement in our workflows.

4.5.2. Evaluation of Second choice

The evolution of second choice percentage after applying action plan is presented as follows:

Table 4 . Evolution of Second-choice Percentage

Month	% Second Quality Garment	% Second Quality Fabric	% Second Quality Washing	% Second Quality Treatment	% Total Second Quality
February	0.44%	1.78%	0.55%	0.31%	3.08%
March	0.45%	2.08%	0.56%	0.15%	3.24%
April	0.40%	0.90%	0.43%	0.20%	1.93%

Based on the data in Table 6, Figure 13 shows the trend in the percentage of second-choice products

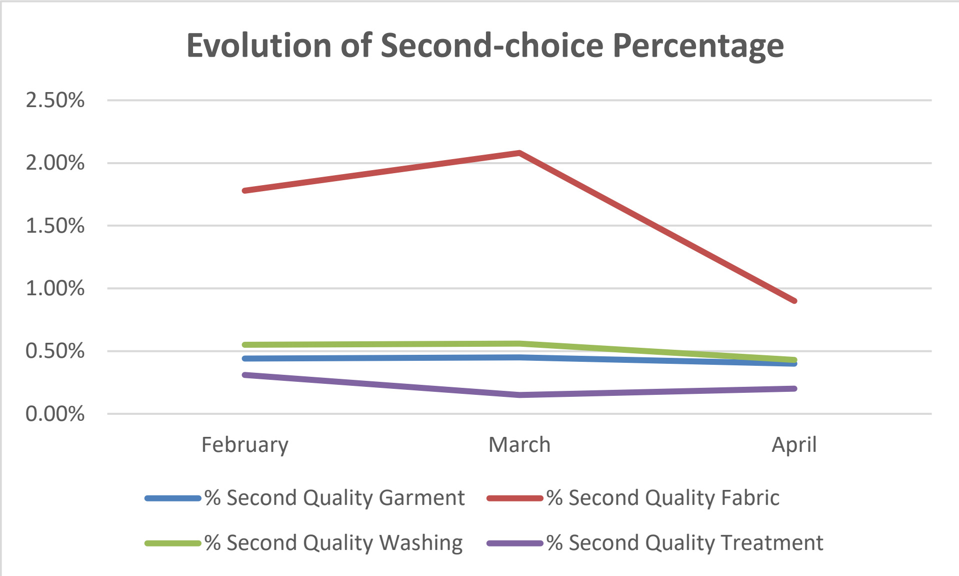

Figure 19.Evolution of Second choice Percentage

This graph illustrates the development of the second-choice percentages for the categories Second Quality Garment, Second Quality Fabric, Second Quality Washing and Second Quality Treatment over the months of February, March and April. The red line, Second Quality Garment, has decreased strongly from around 1.8% in February to approximately 0.5% in April. The second-choice percentages for Second Quality Fabric and Second Quality Washing are on a stable level at approximately 0.5% and 0.3% respectively over the three months. Likewise, the level of the second-choice percentage for Second Quality Treatment is purple and is on a low level. Overall, there is a positive development of second-choice percentages, where the decline in particular applies to garments, indicating an improvement of quality control. The quality of the other categories has been further confirmed as stable.

5. Findings

The findings of this study provide a detailed overview of the quality performance in the workshops and the effectiveness of implemented control measures.

5.1. Workshop Performance

- - Fabric Overconsumption: Workshops C, Delta and Excellence Style have overconsumption of 12% which is 7.26% above the global average of 4.34%. Room for improvement in terms of material efficiency.
- Quilting Losses: The main sources of quilting losses were NS Conf, Nouvelle Génération and Meghatex, all with quilting losses ranging from 12% to 22% depending on the operational conditions and level of employee skills.
- Percentage of first choice Information showing the percentage of first choice materials for each workshop, relative to the expected standard of 97.34%: There are two workshops with a lower-than-expected percentage of first choice materials.
- Second choice percentage Workshop CTV had a second choice percentage of 17% as opposed to an average of 1.7% across all TAVI approaches.
- Repair Rates: According to Hamdatex and Meghatex repair rates for defective textile products ranged from 50–60% which is more than two times the average repair rate of 25.4% found in other investigations. This represents a serious problem that requires urgent action.

5.2 Controller Analysis

- Pareto analyses performed showed that a small group of specific defects were the primary causes of second quality product. The defects investigated were holes, machine stops, broken lycra, and missing threads, and they accounted for an 80% share of all defects.
- More defects were found by washing and other special treatment processes, like stains, scratches and holes, which had not been visible earlier in the production process.
- Additional analysis of the faulty products showed that there was a concentration of defects in certain stages of the assembly process (waistband, hems, pockets, fly and belt loops).

- Stain and grease defects were determined to be the most common type of defect. This is due to a number of different causes, such as inadequate machine maintenance, inadequate cleaning of the machine and inadequate operator behaviour.

5.3. Effectiveness of Action Plans

- A reflection on implemented action plans by workers has shown the effectiveness in reducing rework: total rework has fallen from 25.40% to 21.92% and the number of saved pieces has reached 4780 pieces which amounts to approximately 2096.65 TND.
- Second-quality items accounted for 2.25% of total output, subsequently decreased to 1.93% because of differences in the qualities of fabrics used.
- Continued work to standardize inspection procedures, enhance supplier compliance and address the quality manual.

5.4. General Observations

- The organisation had a clear example of the Pareto principle in action. 20% of the site's repair workshops or defects were accounting for 80% of all quality issues.
- Immediate Action is most effective where it can be concentrated on the most critical areas, i.e., key number of workshops and the greatest number of recurrent defects.
- Sustaining the improvements will depend on ongoing monitoring, operator training and supplier involvement.

6. Discussion & Limitations

6.1. Discussion

- Quality diagnostic achieved to identify in particular workshops and departments with high loss, high consumption or high defect rates.

Action plans included in processes for standardized inspections and rectification of nonconformities, as well as management of supplier specifications led to a decrease in rework and second-quality products.

- Material consumption vs. defect rate vs. cost: The figures show that high material consumption is closely linked with high defect rates and costs.
- Our research verifies that focusing on high-impact defects and high-risk workshops gives the best opportunity to optimize resource allocation and obtain the largest quality gain.
- Visualization of data with the use of Pareto charts and process control charts proved to be an invaluable tool for directing activities.

6.2. Limitations

- Trend over 3 months may not be representative of overall trend.
- Some factors were assessed qualitatively (behaviour of workers, punctuality, and cleanliness of the workshop) and may therefore be influenced by subjective judgment.
- Human errors in recording or reporting data could affect accuracy.
- Variations in fabric quality from suppliers introduced inconsistencies in second-choice rates.
- External variables such as maintenance periods or seasonal fluctuations were not under management control.

7. Conclusion & Recommandations

7.1. Conclusion

- The quality diagnostic and corresponding action plans have been implemented, resulting in an improvement in workshop efficiency and product quality.

A decrease of 3.48% in total rework and a reduction of 0.32% in second choice items.

- Critical defects and high risk workshops have been identified and prioritized for remedial action.
- All our achievements (mentioned above) were possible only due to the standardized methods, alignment of suppliers and our quality manuals.

The findings of this research confirm that regular monitoring, the application of corrective actions to specifically identified anomalies in the weave and the optimization of manufacturing processes can lead to improved quality in textiles.

7.2. Recommendations

- Continuous Monitoring (CM): Continuous Monitoring shall be carried out on high risk workshops and high impact defect types to sustain quality improvements.
- Operator Training: Training of operators and inspectors on an on-going basis to ensure that processes are being executed properly and effectively to prevent defects.
- Supplier Management: Ensure suppliers adhere to all quality requirements, including aqa, aql criteria and uv-marking of defects with traceability.
- Process Standardization: Work continues on updating and finalizing the quality manuals and work instructions for all process stages.
- Long-Term Evaluation: We recommend that users extend the period of observation beyond 3 months to reflect any possible changes during the seasons.
- Preventive Maintenance Maintain high standards of machine and workspace cleanliness to decrease grease, stain and defect levels.
- Data-Driven Decisions Use Pareto analysis and defect mapping to understand what must be addressed in priority and how to best utilize your resources.
- Periodic Audits : Audits are to be carried out periodically at workshops and supplier premises to verify the effectiveness of corrective actions.

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