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Impacto del análisis de operaciones en la productividad de la pequeña empresa de confección textil de Imbabura, Ecuador

Impact of Operations Analysis on Productivity in Small Textile Manufacturing Businesses in Imbabura, Ecuador

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Abstract

This study examines the effects of introducing operations analysis to garment assembly activities in a small business in the Antonio Ante Canton in the province of Imbabura. The methodological framework followed consists of the following steps: 1) selection of garment manufacturing operations, 2) selection of participants, 3) assessment of the initial state of operations, 4) methodical analysis of operations, and 5) suggestions for improvements. The introduction of operations analysis represents an estimated reduction of 18 seconds in cycle time, which translates into a 15.79% increase in productivity. These effects position operations analysis as a methodology applicable to the garment manufacturing company, generating a positive impact on its usual factory work procedures.

Keywords: Operations Analysis, Quality, Clothing, Textile Clothing, Efficiency, Productivity, Production, Textiles.

Resumen

Se estudia los efectos de la introducción del análisis de las operaciones en las actividades de ensamble de prendas de vestir en una pequeña empresa del cantón de Antonio Ante de la provincia de Imbabura. El marco metodológico seguido es la consecución de los siguientes pasos: 1) la elección de las operaciones de confección, 2) la elección de los participantes, 3) la evaluación del estado inicial de las operaciones, 4) el análisis metódico de las operaciones y, 5) la sugerencia de mejoras. La introducción del análisis de operaciones representa una disminución estimada de 18 segundos en el tiempo de ciclo, lo que se traduce, en el aumento de la productividad en un 15,79%. Tales efectos posesionan al análisis de operaciones como una

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metodología aplicable a la empresa de confección, que genera un impacto positivo en su proceder habitual de trabajo en fábrica.

Palabras claves: Análisis de Operaciones, Calidad, Confección, Confección Textil, Eficiencia, Productividad, Producción, Textil.

1. Introduction

The business fabric dedicated to the manufacture of goods and services constitutes a reference point for national development (Orellana, Pinos, Tonon, Reyes, & Cevallos, 2020). In this context, we find companies dedicated to the manufacture and industrial production of clothing, predominantly micro, small, and medium-sized enterprises. In the province of Imbabura, companies engaged in the manufacture of clothing account for 35% of all companies in the manufacturing industry, with a distribution of 89.8% micro-enterprises, 9.2% small enterprises, and 0.9% medium and large enterprises. Although the main contribution of this important business group is not economic, its impact is significant in terms of direct job creation and productive linkages with other sectors (Cervantes & Oviedo, 2019). In the province of Imbabura, affiliated labor employment reaches 30%, ranking first nationally in terms of the concentration of the textile manufacturing industry within the provincial territory (National Institute of Statistics and Census (INEC), 2017).

The importance of the clothing manufacturing business group at the local and national levels contrasts with the problems related to the technification of production processes and operations, where, according to Miño, Moyano, & Santillán (2019), constant attempts are made to achieve the highest levels of productivity. For example, in many cases, the efficient use of resources is hindered by the choice of module organization and workstations with disproportionate loads, which disrupts the smooth flow of production levels, generally increasing fixed costs and delays in the delivery of the final product within the timeframes agreed upon with customers (Sánchez, Ceballos, & Torres, 2014). Other unfavorable aspects include the insufficient guarantees provided by working conditions in terms of operator safety and health (Alcívar, Espinoz, Arteaga, & Escobar, 2018). Furthermore, Barrios, Contreras, and Olivero (2019) argue that garment companies, especially small and micro-enterprises, tend to show little interest in testing and adopting methods or techniques that contribute to improving process efficiency. All of this aligns with García, Tumbajulca, and Cruz (2021), who state that one of the distinctive features of textile manufacturing is its limited capacity for product innovation, reduced process innovation, and the desire to preserve traditional work practices and procedures.

On the other hand, operations analysis is a method applicable to the dynamics of manufacturing companies, with the aim of examining all the productive and non-productive elements of an operation, improving productivity per unit of time, and reducing unit costs, with the purpose of maintaining or improving the quality of the final product (Niebel & Freivalds, 2014). The purpose is to create a more efficient method of performing the work, simplifying operating procedures, better managing materials, and using equipment more effectively (Hodson, 1996). The effect of introducing operations analysis in companies outside the textile manufacturing industry is widely described in literature. In this regard, Rodríguez, Chaves, and Martínez (2018), through the use of statistical graphical methods in operations analysis, reduced work operations in the fabric dyeing area, achieving an increase in productivity from 75% to 95% and a decrease in rework and defects in the final product. Díaz (2012), through a systemic study of operations using standardized work checklists to monitor staff work activities in the provision of specialized technology and information services, achieved a 5% increase in productivity. Montaño, Preciado, Robles, and Chávez (2018), through an operations study comparing micro-movements performed in two different working methods in the same manual grape packaging process, demonstrate that these differ in the number of movements performed and, therefore, in the final working time, due to their organization.

The brief context of textile manufacturing companies discussed so far highlights two issues: on the one hand, the importance of this business group in terms of direct job creation and, on the other, the problems identified in the management of work and factory operations. At the same time, operations analysis is conceived as a method that has been tested in different industries to enhance work and activities at the factory level. It is part of the field of methods engineering, which focuses on the design, creation, and selection of the best working methods, processes, tools, equipment, and skills for manufacturing a product, based on the final specifications (Niebel & Freivalds, 2014). It is therefore worth questioning whether the aforementioned problems identified in textile manufacturing companies can be addressed, at least in part, through the application of operations analysis.

Therefore, this study aims to determine the effect of introducing operations analysis in a small clothing manufacturing company, as a means of seeking and consolidating applied knowledge that contributes to the advancement of current knowledge in textile manufacturing. The article is organized into an introduction, methodology, results, and finally, conclusions, recommendations, and acknowledgments.

2. Theoretical Framework.

This work is based on the principles of Methods Engineering and Operations Analysis methodology. The theoretical framework of the elements involved is presented below.

2.1. Methods Engineering

Methods engineering is part of the discipline of studying work in industrial manufacturing environments. It is a compendium of methods and tools whose application promotes the improvement of production processes (Wilke, Grewe, Thavathilakarjah, Anacker, and Dumitrescu, 2023). Fundamentally, it seeks to find the most efficient way to operationalize activities and work, which implies reducing costs without compromising working conditions or the quality of the final product.

This discipline is based on the contributions of various pioneers in the study of work. Frederick W. Taylor (1856-1915), considered the "father of scientific management," laid the groundwork by introducing principles of work efficiency in the late 19th and early 20th centuries. His most influential work, "The Principles of Scientific Management" (1911), revolutionized industrial production by introducing task division and systematic analysis of work methods (Filinich, 2016).

Building on this foundation, Frank (1868-1924) and Lillian Gilbreth (1878-1972) expanded the field with their innovative studies of motion in the early decades of the 20th century. Their development of the concept of "therblig" (1914), a unit of measurement for analyzing and optimizing each movement at work, represented an important advance in understanding and improving work efficiency, with a particular emphasis on reducing worker fatigue.

Subsequently, Ralph M. Barnes (1900-1984) consolidated this knowledge in his seminal work "Motion and Time Study" (1949), which became a key reference for the theory and practice of methods engineering (Duran, Cetindere, and Emre Aksu, 2015). Benjamin Niebel (1907-1996) continued this legacy with his own significant contributions, particularly through his work Motion and Time Study (1962). His structured approach to operations analysis not only strengthened existing principles but also expanded their application beyond the manufacturing sector.

In the modern era, Kjell B. Zandin has made contributions through his work as editor-in-chief of "MOST Work Measurement Systems" and his book "MOST: Work Measurement Systems" in 2003 (Gharajedaghi, 2012). Zandin has modernized work measurement systems by developing and refining the MOST (Maynard Operation Sequence Technique) system, which represents an evolution in work measurement by providing a faster and more accurate method for establishing predetermined time standards. His work has been instrumental in adapting methods engineering to the needs of modern industry, particularly in automated manufacturing and lean production environments (Hazarika, Dixit, & Davim, 2019).

The fundamentals of methods engineering focus on the study of time and motion, operations analysis, ergonomics and work design, work measurement, simplification and standardization, and continuous improvement. The most popular methods and tools include process diagrams, instruments for time analysis and study, work sampling, predetermined time systems (MODAPTS, MTM), and motion analysis. The specialized literature includes various improvement techniques such as value-added analysis, the 5S method, Pareto analysis, cause-and-effect diagrams (Ishikawa), and SMED (Single Minute Exchange of Die) (Hough & White, 2001).

Currently, classic methods engineering tools are complemented by advanced technologies such as digital motion analysis (motion capture systems, 3D ergonomic simulation software, biomechanical analysis, and wearable sensors), Industry 4.0 tools (manufacturing execution systems, digital twins, IoT, and Big Data), and specialized software (ProModel, Arena Simulation, and Tecnomatix). Agile methodologies are also used in production (Scrum, Kanban, Design Thinking, and Lean Six Sigma Digital), along with advanced techniques such as augmented reality, artificial intelligence, machine learning, blockchain, and RPA, as well as digital collaboration tools and quality control systems (Hazarika, Dixit, and Davim, 2019).

2.2. Operations analysis

An operation is a specific stage within a process, where tasks are performed to transform raw materials into finished products or advance their production. Examples include cutting, assembly, and welding. In this context, operations analysis is integrated into Work Engineering (Yépez, Muyulema, Ormaza, and Sánchez, 2019). It is positioned as a useful methodology for the dynamics of manufacturing companies, allowing for the evaluation of both the productive and non-productive components of a set of operations. Its objective is to increase productivity per unit of time and reduce costs per unit, seeking to maintain or improve the quality of the final product (Niebel & Freivalds, 2014). This methodology aims to develop a more efficient way of working, simplifying operating procedures, optimizing material handling, and utilizing equipment more effectively (Hodson, 1996).

Analyzing individual operations allows specific problems to be identified and solved, optimizing resources and improving productivity without interrupting the entire process. This approach facilitates rapid and controlled changes, with lower cost and lower risk, contributing to continuous improvements in quality and efficiency without the need to intervene in the entire production system (Kosky, Balmer, Keat, and Wise, 2021).

In the textile manufacturing industry, operations analysis has been specifically adapted to meet the particular needs of the sector. In this regard, Yépez (2019) proposes a tool for the analysis and improvement of manufacturing operations, structured around five phases: 1), selection of problematic operations, 2) selection of participants (company representative, analyst, and operator), 3) measurement of the initial state (defects, costs, productivity), 4) detailed analysis of operations (purpose, inspection, materials, machinery, working conditions), and 5) development of an improvement proposal with an action plan. Its distinctive feature is the integration of knowledge in manufacturing, quality, materials management, machinery, and working conditions, including safety and ergonomics, which sets it apart from other business management tools.

3. Methodology

The methodological framework is based on the application of the "diagnosis for the analysis and improvement of clothing manufacturing operations" tool proposed and published by Yépez, Muyulema, Ormaza, and Sánchez, 2019. It entails five phases of application: 1) selection of garment manufacturing operations, 2) selection of participants, 3) evaluation of the initial state of operations, 4) methodical analysis of operations, and 5) suggestion of improvements.

The operations selected for operational analysis involve the assembly of girls' underwear in a small company located in the canton of Antonio Ante in the province of Imbabura. Three types of participants were involved throughout the process: the operators, responsible for carrying out the selected work operations on a daily basis; the company representative, responsible for planning and controlling all the operations within the production process; and work analysts, responsible for observing and collecting sufficient data to represent the dynamics of work operations within the factory context in order to propose potential improvements. The first two are company staff and have experience in garment manufacturing processes. The remaining participants, the student and the research professor, represent the contribution of academia to the company. Both have ongoing and completed training, respectively, in the areas of methods engineering and operations analysis.

To measure the initial state of operations, the operations productivity indicator (equation 1) is used, which relates outputs (units produced) and inputs (resources used).

$$P = \frac{\text{Salidas}}{\text{Entradas}} \quad (1)$$

Where:
P = Productivity
Output = Units produced
Inputs = Resources used [Raw materials; Labor; Machinery; Others]

The systematic analysis of operations involved subjecting the selected work operations to a series of questions designed to identify opportunities for improvement, aiming to examine: a) the purpose of the manufacturing operation; b) the inspection requirements for the garment or its parts; c) the correspondence of the textile bases and inputs used with respect to the prototype; d) the handling of textile bases and inputs; e) the performance of machinery and tools; and finally, f) the analysis of working conditions.

Once each improvement criterion has been analyzed, participatory research is carried out as a democratic and collaborative process, in which all parties involved propose one or more strategies for improving the operations analyzed. Subsequently, a proposal is develope d, describing the suggested improvement, with preference given to the one expected to have a considerable impact on the diagnosed productivity. The impact of the proposed improvement is measured based on the rate of change in productivity (%ΔP), calculated as the ratio between the productivity of the work operations assuming implementation of the improvement and the productivity of the same operations in their usual or initial state (Equation 2).

$$\%\,\Delta P = \left(\frac{\text{Productividad final}}{\text{Productividad inicial}} - 1 \right) x\ 100 \qquad (2)$$

4. Results

4.1 Representation of assembly operations

After selecting assembly operations as the object of the operations analysis, the first step in understanding them is to abstract them from the manufacturing context (Figure 1).

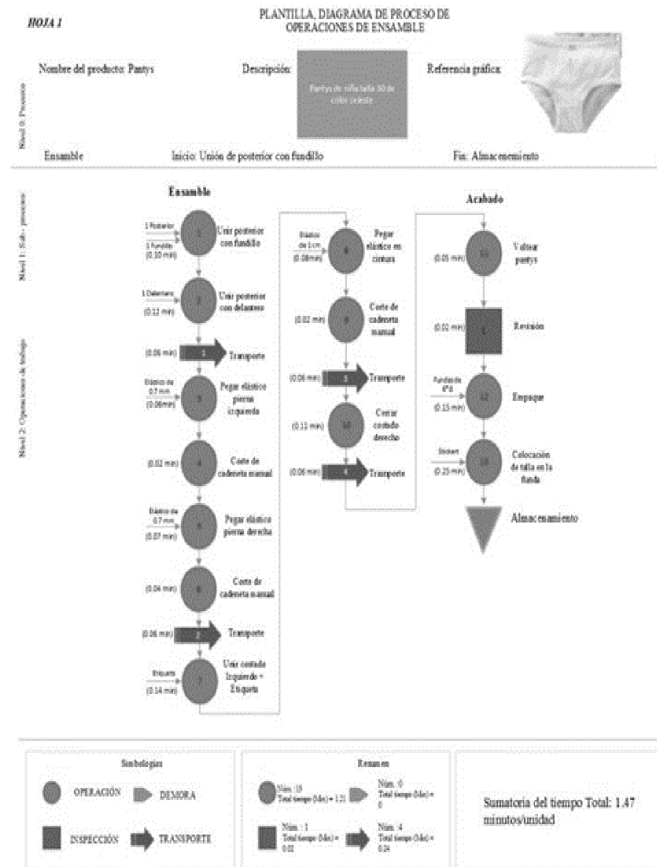

Figure 1 . Representation of assembly operations. Source: (Portilla, 2020)

Assembly operations consist of a work dynamic divided into various types of activities, including transformation operations, delays, inspections, and transport. Their workflow is linear and sequential, with activities arranged one after another, such that the completion of one is required for the execution of the next. The process begins with the joining of the back and bottom and ends with the attachment of the label to the finished garment. The cycle time is 1.47 minutes per unit, which corresponds to a productivity of 0.68 units per minute.

4.2 Analysis of operations

The first step was to analyze the purpose of the operations, resulting in the following conclusions: a) the purpose of the operations could be fulfilled in an alternative way, through a renewed distribution of the assembly area plant; b) several of the contractual activities could be eliminated or combined, perhaps by eliminating unnecessary movements when placing labels on each garment with the right hand during the activity of joining the first side of the panty; and c) the current sequence of activities is correct.

Next, the inspection requirements for the parts or tasks were analyzed, with the aim of determining whether the manufactured garment complies with the design specifications in terms of measurements, seams, and stitches. It was then concluded that: a) the operators have correctly identified the specifications of the garments, considering that they have been provided with the patterns for each size in advance, and that the operators have extensive experience in operating the machinery (more than 3 years); b) it is not necessary to eliminate inspection tasks, as it appears that new ones need to be implemented due to the presence of garments with faulty seams; c) it is not necessary to establish other quality requirements; and d) current tolerances should be maintained. Although there are quality issues with the garments, this is not attributable to the operator, but to the quality of the threads used in the seams. This will be discussed in more detail below.

Regarding the analysis of the textile bases and inputs used, it was observed that the main raw material used by the company is jersey fabric composed of 65% polyester and 35% cotton. The supplies include 100% polyester thread, 100% polyester silk thread, 0.7 mm and 1 cm wide 100% polyester elastic, printed figures, and 100% polyester labels. From this analysis, it can be concluded that: a) the textile bases are appropriate in terms of composition and thickness, however, they could be improved by sourcing from a better supplier; b) not all of the threads are adequate. In particular, for the chain stitch overlock machine, the current threads need to be replaced with others with a no. 90 thread count in order to eliminate seam defects.

During the analysis of the handling of the textile bases, it was determined that the activities carried out for this purpose are mainly manual. However, improvements could be made by optimizing the distribution of materials to reduce the distance traveled from the cutting area, as well as by implementing a hanger with size-based divisions to reduce the time spent searching for and selecting materials.

The analysis of the machinery and tools yielded the following results: a) the overlock machinery currently used for garment assembly has been in use for 12 years, exceeding the useful life recommended by the manufacturer. Thus, a substantial improvement could be the replacement of the four-thread overlock machinery with one designed for light-, medium-, and heavy-duty operations, with, hemming at the beginning and end of the seam, as required for underwear and lingerie manufacturing. b) The current machinery requires maintenance in terms of replacing parts such as upper blades and continuous lubrication. c) Handling, adjustment, and calibration are correct due to the experience of the operators. d) machine regulation is deficient in this regard, e) the tools are appropriate for the operations, including scissors and screwdrivers of different types and sizes, all of which are in good condition; and f) the tools are located correctly and are stored near the operators according to type.

Regarding working conditions, the following conclusions were made: a) although the operators do not have visual difficulties, no technical study has been conducted on the lighting of the work tables to ensure correct lighting levels appropriate to the complexity of the task; b) noise is present in the work area, but a technical noise study is required to establish whether the current noise levels exceed the established regulatory limits; c) in terms of ambient temperature, operators do not experience any discomfort; d) no gases and/or vapors were perceived by operators; e) no hazardous conditions were identified that could cause workplace accidents, such as obstacles on the floor, unprotected machinery, entrapment, or contact with hot surfaces; f) in terms of workplace ergonomics, the chairs are unsuitable; and g) production volumes are as planned.

The analysis of working conditions with regard to physical risks was limited, considering that the company does not have the necessary equipment to measure lighting conditions, noise, ambient temperature, the presence of particles, gases, vapors, etc. Assembly operations require the use of manufacturing machinery in a seated position, in an 8-hour workday with a daily production quota, so determining the ergonomic risk of the workstations involved in assembly operations requires ergonomic studies using specific methods.

Finally, the improvement proposal is set forth, detailing the actions recommended to improve operations in light of the analysis presented above.

The proposed improvements comprise a set of strategies applicable to the current assembly operations in both the short and medium term.

In the short term, the following measures are suggested: a) reorganizing assembly operations through a revised plant layout, b) implementing a basic scheduled maintenance program for machinery, c) replacing the threads used for seaming, and d) providing ergonomic chairs. In the medium term, the proposal includes purchasing basic clothing manufacturing machinery, but this strategy is currently not considered a priority by the company's current members.

4.3 Impact of the introduction of operations analysis on productivity

Although the main objective of the research is not the deployment of strategies to improve the proposed operations, below is a suggested outline of a new plant layout to better organize assembly operations (Figure 2), as well as an estimate of the reduction in cycle time per unit for each of the proposed short-term strategies (Table 1).

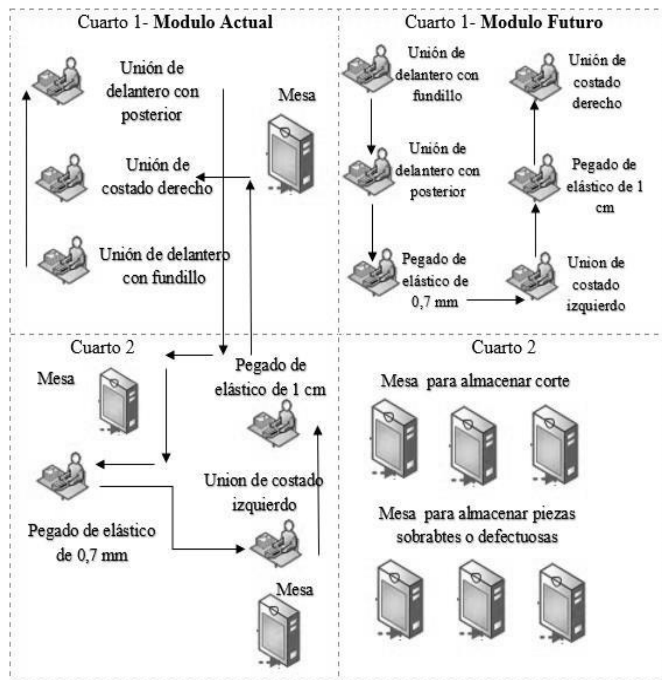

Figure 2. Proposed plant layout. Source: (Portilla, 2020)

Table 1. Estimated reduction in cycle time per unit for each of the short-term strategies.

No.	Strategies	Seconds	Observations
1	Better organize assembly operations through a new plant layout.	12	The new plant layout allowed for the reduction of several operations, proximity between stations, and greater flow of work-in-process and finished inventory.

2	Implement a basic scheduled maintenance program for machinery	2	Machinery maintenance and material replacement (threads) are expected to reduce the percentage of units with failures per workday. This would translate into an increase in units per day and, therefore, a reduction in cycle time.
3	Replace the threads used in seams with more resistant ones.	2	
4	Provide ergonomic chairs for operators	4	It is estimated that reducing postural strain by providing chairs will increase the number of units produced per day, which translates into a reduction in cycle time.
	Total:	**18 seconds per unit**	

Source: (Portilla, 2020)

The reduction in cycle time of 18 seconds per unit is equivalent to a cycle time of 1.27 minutes per unit. This represents a productivity of 0.787 units per minute.

Using equation 2, a productivity increase of 15.79% was estimated (Equation 3).

$$\% \Delta P = \left(\frac{0{,}787}{0{,}680} - 1 \right) x\ 100$$

$$\% \Delta P = 15{,}79\% \qquad (3)$$

5. Conclusions

Local and national textile manufacturing companies, predominantly micro and small businesses, represent a substantial pillar of the country's development, their main contribution being the generation of direct employment. Despite their importance, this niche business sector faces operational and work-related challenges that negatively affect productivity.

The introduction of operations analysis in the small company under study enabled a comprehensive review of the interior assembly activities for girls' clothing. This review considered the purpose of each operation, the control requirements for the garment and its parts, the textile bases and inputs used, the handling of textile bases, the machinery and tools used, and the working conditions. The overall aim was to propose improvement strategies.

After estimating the reduction in cycle time from the possible application of the proposed improvement strategies, a decrease of 18 seconds was estimated, corresponding to an increase in productivity of 15.79%.

The analysis of garment manufacturing operations not only identified opportunities for improvement in areas of weakness but also highlighted the strengths of the company and its employees regarding garment assembly operations.

Consequently, the empirical results presented in this research suggest that operations analysis is a methodology applicable to garment manufacturing companies, with a positive impact on productivity. This methodology not only draws on the experience of those who operate the garment manufacturing processes as a source of insight, but is also strengthened by the participation of staff with professional training in the area, leveraging their knowledge and mastery of the principles and practices of work methods engineering.

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