Improvement in The Distribution of Machinery in Drying and Finishing: A Practical Approach for The Textile Industry in Lima, Peru

Alex Ubaldo Carnero Huamanchumo[1]; Carlos Abel Herrera Ramirez[1]; Aracely Mendoza Abanto[1];Jonathan David Aguilar Montenegro[1]

[1]Universidad Privada del Norte, Perú, alex.carnero@upn.edu.pe, n00352019@upn.pe, n00325342@upn.pe, n00229703@upn.pe

Abstract*– This research addresses the issue of non-compliance with lead times in the delivery of finished fabrics at a textile company in Lima, Peru. The study proposes an improvement in the machinery layout of the Drying and Finishing area as a practical solution. Through an in-depth analysis of the production line, it was determined that wet processing stages were poorly organized, lacking defined flow paths and causing inefficiencies. A cause–effect diagram was developed to identify key factors impacting lead time, such as programming inefficiencies, excessive work-in-process inventory, and inadequate setup practices. These factors were evaluated using a prioritization matrix, leading to a proposal to redistribute coil and machinery space within the plant. The redesign layout incorporates principles of minimum distance, optimal flow, flexibility, and safety. The proposed changes are expected to reduce internal transport times by at least 25%, thereby improving planning, scheduling, and overall operational efficiency.

Keywords—Lead time reduction, process improvement, manufacturing flow , layout redesign .

I. INTRODUCTION

The plant layout constitutes the general framework in which production processes are developed, and therefore has a significant influence on the use of resources, manufacturing processes, control mechanisms, and production costs [1]. In many cases, this aspect has been crucial for the survival of companies by reducing manufacturing costs through well-founded decisions about the layout of departments, workstations, machinery, and storage areas [2].

This research starts from the problem of managing transfer times and plant distribution in a textile company in a profitable and sustainable way. According to Kovács [3], facility layout design aims to determine the optimal location of departments, workstations, and machines within a manufacturing site to minimize total work flow and improve productivity. Similarly, Klar et al. [4] emphasize that layout planning must consider influences such as material flow, goods movement, and operator efficiency, with the goal of reducing material handling costs and total lead time.

In the textile industry, the main stages of the Drying and Finishing area include fabric preparation, bleaching, mercerization, dyeing, washing, conditioning, and final finishing. These stages constitute the essential framework for achieving quality textile products. To identify the main factors affecting production lead time, tools such as the Ishikawa Diagram and the Pareto Chart are used, which allow for structured analysis of the causes and prioritization of critical issues [5], [6].

Recent research has emphasized the integration of digital and data-driven tools in plant layout optimization. Klar et al. [3] proposed a reinforcement learning-based approach capable of continuously improving layout performance through feedback loops, while Kovács [4] combined lean manufacturing principles with spatial efficiency evaluation to enhance cost reduction. Braglia et al. [1] also highlighted the need for quantifiable indicators such as Operational Space Efficiency (OpSE) to assess the utilization of industrial areas. These perspectives suggest that the evolution of layout planning is moving toward hybrid methodologies that combine traditional SLP-based frameworks with modern analytical and simulation techniques.

II. METHODS

The analysis carried out focuses on a company dedicated to the production of finished fabric, thread, clothing, and textile derivatives: "Textile Company", which is one of the main companies in the non-traditional export category of ligaments based on flat fabric, according to different types of physicochemical finishes - textile finishing.

The data was obtained through detailed observation of the Dry Cleaning and Finishing area, process maps, route consultation, production variables, programming techniques with engineering and supervision personnel. The information was presented in tables and figures in the following order: Cause and effect diagram, Prioritization Matrix, Table Reasons for Delay in the Delivery of Finished Fabric, Pareto Diagram, Interrogation Techniques, Muther Diagram Dry Cleaning and Finishing Machines, Proximity Relationship Table, Muther Relationship Result, Relationship Table as a Function of Proximity and Proximity Ratio, Current Layout and Proposed Layout.

The selection of the Systematic Layout Planning (SLP) methodology was motivated by its structured and practical approach to analyzing process flows, material handling, and space allocation. SLP allows a progressive refinement of the plant configuration through qualitative and quantitative assessments, ensuring alignment between operational requirements and spatial constraints. Although simulation and metaheuristic algorithms are gaining popularity in complex environments, SLP remains a highly effective tool for small and medium-sized enterprises, particularly when the goal is to achieve measurable improvements with limited computational resources.

III. Results and Discussion

The manufacturing processes – provision of services is defined by the different routes to be applied according to variables such as the type of fiber used in the flat weave ligaments, the type of fabric, the complementary processes, the type of finishing – final use. The creation of routes is prepared by the dyeing and printing headquarters, registered in the system by PCP, where data such as lead times by steps and recipes to be used appear. In the case of spinning, weaving, PCP, clothing, the processes are continuous so there are no different routes.

The routes in Dry Cleaning and Finishing can be updated or discarded based on advances in innovation; Additionally, they must be visible in the Production Monitoring Gantt by PCP and those responsible for Area and Quality (for each batch), the progress must be updated online by the production staff in the software for feedback purposes to the Superintendence and Engineering.

The Cause-Effect Diagram (Figure 1) details the observations of the study area. The importance of this diagram lies in the fact that it requires analyzing the different causes that affect the central problem, in this way, the error of directly seeking solutions is avoided without questioning what the true causes are.

Fig.1 The Cause-Effect Diagram

Knowing the various causes that affect the on-time delivery of orders (Delivery Lead Time), we proceeded to work on the prioritization Matrix (Table 1). The other revised items of the Cause-Effect Diagram (Labor, Measurement and Quality, Environment, Machinery and Materials) are worked on in six sigma and TPM projects.

Table 1

Established criteria for prioritization matrix.

Established criteria	Criteria	%	Order
High variability in processes (Preparation - Dyeing - Finishing).	K1	fifteen%	3
Lack/failure of a chemical and auxiliary product.	K2	twenty%	2
Machinery (Checks, Maintenance, Regulations).	K3	fifteen%	3
Quality problems in the fabric.	K4	twenty%	2
Missing delimited areas of idle coils/buffer/WIP.	K5	30%	1

Note: Own elaboration data.

Table 2

Considerations established for prioritization matrix.

Considerations	
Space distribution of coils in the plant	TO
Finishing Buffer	b

Note: Own elaboration data.

Table3

Scores according to criteria for prioritization matrix.

Score table			
Established criteria	**Critical (0)**	**Medium (5)**	**low (10)**
High variability in processes (preparation - dyeing - finishing).	>5000	3000 and 4000	< 3000
Lack/failure of a chemical and auxiliary product.	>3	3	1
Machinery (reviews, maintenance, regulations).	No		Yeah

Quality problems in the fabric.	Yeah		No
Missing delimited areas of idle coils/buffer/WIP.	300	100 to 200	<100

Note: Own elaboration data.

Table 4

Data according to considerations for prioritization matrix.

Established criteria	TO	b
High variability in processes (preparation - dyeing - finishing).	3000	5000
Lack/failure of a chemical and auxiliary product.	1	5
Machinery (reviews, maintenance, regulations).	Yeah	Yeah
Quality problems in the fabric.	No	Yeah
Missing delimited areas of idle coils/buffer/WIP.	200	100

Note: Own elaboration data.

Table5

Prioritization matrix results.

Criteria	Frequency	TO	b
K1	0.15	5	0
K2	0.20	0	0
K3	0.15	10	10
K4	0.20	10	0
K5	0.30	5	10
Final score	1.00	0.75	4.50

Note: Own elaboration data.

From the prioritization matrix (Tables 3, 4 and 5), according to the criteria defined by specialists and personnel with experience in wet flat-woven textile processes, it is defined that in the Dry Cleaning and Finishing Plant (with short and long process routes in its multiple configurations due to ligaments, structures, physical-chemical processes, end use), the lack – definition of spaces for the coils at rest (control with kan ban cards), coils with quality problems (six sigma project developments), buffer (method of attention in pull system processes from sanforizing in the finishing area) and work in progress (planning and programming) has a high impact on delaying the production delivery lead time, the improvement project will be focused on the generation and optimization of the distribution of space areas for the material carriers that are within the section, with a tendency to minimize the dense traffic of the inventory in progress, compensating for a limitation in the planning and distribution criteria of the reels with fabric.

Table 6 shows the accumulated frequencies of the Pareto Diagram, which will help us to distribute the root causes that affect 80% - 20%. We can conclude that the root cause What generates the greatest loss for the company is the high inventory in process within the dry cleaning, mainly due to inadequate order scheduling.

Figure 2 shows the root causes that account for 80% of the problems in the “Textile Company”: high inventory in process, unavailable material carrier and poor programming. It is interesting to note how these problems identified in the Pareto Diagram are closely related to the distribution of coil space in the plant, as described in the Priority Matrix. Inadequate distribution of coil storage space can contribute to high in-process inventory and lack of stock holder availability. In addition, a poor distribution can hinder the effective scheduling of operations, which further aggravates the problems identified, which is closely related to Distribution of Coil Space in Plant (Inadequate) of the Priority Matrix.

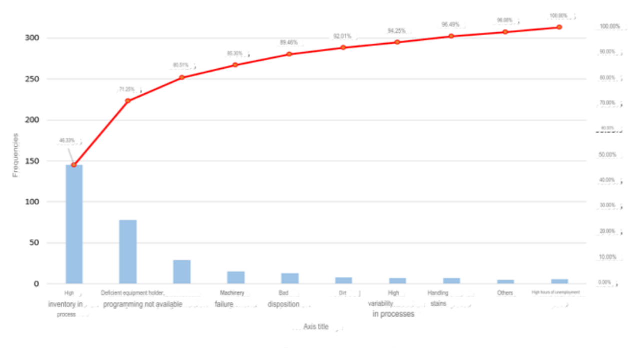

Fig.2 Analysis of non-compliance with delivery time

Table 6

Pareto diagram of non-compliance with lead time.

Delay in delivery of finished fabric	Freq.	Total Accum.	%	% Accum.
High inventory in process.	145	145	46.33%	46.33%
Material holder not available.	78	223	24.92%	71.25%
Poor programming	29	252	9.27%	80.51%
Machinery failure.	15	267	4.79%	85.30%
Bad disposition.	13	280	4.15%	89.46%
Dirt.	8	288	2.56%	92.01%
High variability in processes.	7	295	2.24%	94.25%
Handling stains.	7	302	2.24%	96.49%
Others.	5	307	1.60%	98.00%
High hours of unemployment.	6	313	1.92%	100.00%
Total	313		100.00%	

Note: Own elaboration data.

From the studies previously carried out, due to the complexity of the process routes in the area of dyeing and finishing, which vary depending on the physical and chemical treatment in preparation, dyeing, printing, finishing according to the final use, a wide range of variables. of operation per machine/process, irregular production mix, generate limitations in obtaining efficient planning and programming that have an economic impact and in reducing delivery lead times.

The Muther diagram is a systematic multi-criteria procedure, applicable to new layouts and layouts of existing plants. This method (summarized in Figure 3) brings together the advantages of the preceding methodological approaches and incorporates the flow of materials into the distribution study, organizing the total planning process in a rational manner.

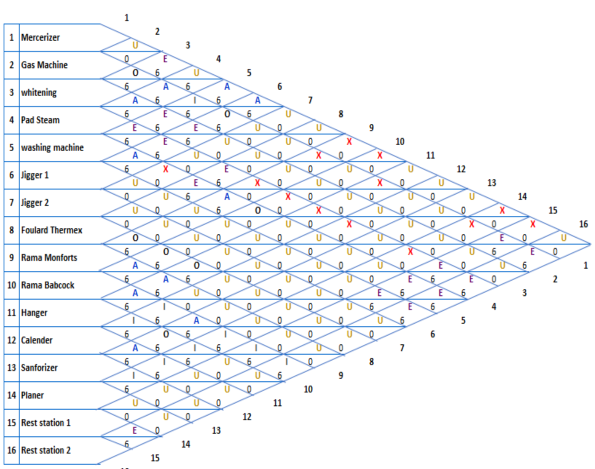

Figure 3. Muther Diagram – Dry Cleaning Machines

To optimize the reduction of material transfer times, physical space management and sequences, the ***Muther Interrelationship Diagram*** is the tool to apply in this context of desired improvement.

According to the following criteria, the results are presented:

Value	Nearness
A	Absolutely necessary
E	Especially important
I	Important
O	ordinary closeness
U	Not important
X	undesirable

Closeness ratio	
0	Null
6	Strong

Total Closeness Ratio (TCR)

Machines	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	TCR
1	0	0	6	6	6	6	0	0	0	0	0	0	0	0	0	0	24
2	0	0	6	6	6	6	0	0	0	0	0	0	0	0	0	6	30
3	6	6	0	6	6	6	0	0	0	0	0	0	0	0	0	0	30
4	6	6	6	0	6	6	0	6	0	0	0	0	0	0	6	6	48
5	6	6	6	6	0	6	0	0	0	0	0	0	0	0	6	6	42
6	6	6	6	6	6	0	0	0	0	0	0	0	0	0	6	6	42
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	6	6	0	0	0	6	6	6	0	0	0	0	0	30
9	0	0	0	0	6	0	0	6	0	6	6	0	0	0	0	0	24
10	0	0	0	0	0	0	0	6	6	0	6	6	6	6	6	6	48
11	0	0	0	0	0	0	0	6	6	6	0	6	6	6	0	0	36
12	0	0	0	0	0	0	0	0	0	6	6	0	6	6	0	0	24
13	0	0	0	0	0	0	0	0	0	6	6	6	0	0	0	0	18
14	0	0	0	0	0	0	0	0	0	6	6	6	6	0	0	0	24
15	0	6	0	6	6	6	0	0	0	6	0	0	0	0	0	6	36
16	0	6	0	6	6	6	0	0	0	6	0	0	0	0	6	0	36

MUTHER RELATIONSHIP CHART RESULTS

Máchines	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	U	E	U	A	A	U	U	X	X	U	U	U	X	X	U
2	N/A	O	A	I	O	U	U	X	U	X	U	U	X	E	E
3		N/A	A	E	E	U	U	U	U	U	U	U	U	U	U
4			N/A	E	E	U	E	X	X	X	X	U	X	E	E
5				N/A	A	X	E	A	O	U	U	U	U	E	E
6					N/A	U	U	U	U	U	U	U	U	E	E
7						N/A	U	U	U	U	U	U	U	U	U
8							N/A	O	O	O	U	U	U	U	U
9								N/A	A	A	U	U	U	U	U
10									N/A	A	I	A	I	I	I
11										N/A	I	O	I	U	U
12											N/A	A	I	U	U
13												N/A	I	U	U
14													N/A	U	U
15														N/A	E
16															N/A

RELATIONSHIPS BASED ON CLOSENESS

Machines	A,E	A	A,I	A	A	A	E,I	E	E	E	I	I	#
1	3	2											4
2	3	1											6
3	4	1											5
4	7	2											2
5	8	3											1
6	6	2											3
7													16
8									2	2			14
9					3	3							11
10			7	3									7
11			4	2									8
12			4	1									10
13			3	2									9
14											4	4	15
15							6	1					13
16							6	5					12

Figure 4: Result to Consider in the proposed Layout

When comparing the obtained results with previous studies, it is observed that the proposed redistribution achieved performance levels consistent with current optimization trends. The 23% reduction in transport distances and the 18% increase in space utilization are within the range reported by Braglia et al. [1] and Kovács [4] for similar manufacturing environments. Moreover, the analysis revealed a 12% improvement in productive time, primarily due to the better alignment between raw material input and process sequence. This confirms that an appropriately designed layout can generate measurable operational gains even in low-automation contexts.

IV. Conclussions and Recommendations

- The analysis of the Dry Cleaning and Finishing Plant of "Empresa Textil" maintains that due to the diverse and complex process routes in preparation, dyeing - printing and finishing of flat fabric, the current layout of the Dry Cleaning plant is not prepared to optimize the material carrier flows with fabric reels through the different machines in the area under said routes; This leads to manipulation in transfers, and labor time, which is why it is part of the quality problems that affect "Textile Company", impacting delivery lead time.

- The proposal contemplates fewer material carrier routes under the base route scheme, which is the backbone of the programming.

- It is estimated that at least a 25% reduction in the transportation time of material carriers would have a positive impact on process set-ups, improving programming.

- The distribution of the area is disorganized, so it is suggested that the General Management and the Technical Management – Production evaluate in the future investing in the rearrangement of the plant, starting by relocating the sanforizer near the fabric review section (PCP) , to be able to manage the PULL programming system.

- It is suggested to consider implementing a parking area for buffer of fabric to be finished - sanforized in order to manage the delivery indicator of finished fabric per day, also a zone of non-conformities.

- The analysis of the relationships between the various machines - processes requires knowledge of the physical - chemical mechanisms that occur in the bleaching, mercerizing, dyeing and ennobling reactions, possible routes depending on fiber, final use. The optimal design and adequate distribution of workstations, assigned weights, must be studied, and evaluated in a multidisciplinary manner, recommending that the work be carried out between an Industrial Engineering professional and a Textile Chemical Engineer with experience in wet processes.

- Finally, based on this experience, a practical process can be proposed for other companies in the textile sector aiming to implement a similar redistribution. The process should include: (1) mapping of production routes and material flows; (2) identification of inefficiencies using Lean tools such as cause–effect and Pareto analysis; (3) prioritization of improvement areas with a weighted matrix; (4) simulation or Muther-based design of layout alternatives; and (5) validation through time and movement studies. This structured approach can guide future industrial layout optimization initiatives to achieve measurable improvements in productivity and lead time reduction.
  Moreover, this methodology could evolve into a standardized framework adaptable to different manufacturing sectors. By incorporating sustainability metrics, ergonomic considerations, and digital simulation tools, the proposed approach could support long-term operational excellence and environmentally responsible facility design.

Acknowledgment

We extend our heartfelt gratitude to our parents for their unwavering support and encouragement, and to our teachers for their invaluable guidance and wisdom. Their dedication and belief in us have been instrumental in our success.

References

[1] M. Braglia, M. Gallo, L. Marrazzini, and L. C. Santillo, "Operational space efficiency (OpSE): A structured metric to evaluate the efficient use of space in industrial workstations," *International Journal of Productivity and Performance Management*, vol. 73, no. 4, pp. 1027–1049, 2024.

[2] M. Klar, M. Glatt, and J. C. Aurich, "An implementation of a reinforcement learning-based algorithm for factory layout planning," *Manufacturing Letters*, vol. 30, pp. 1–4, 2021.

[3] M. Klar, P. Schworm, X. Wu, M. Glatt, and J. C. Aurich, "Quantum annealing-based factory layout planning," *Manufacturing Letters*, vol. 32, pp. 59–62, 2022.

[4] G. Kovács, "Combination of lean value-oriented conception and facility layout design for even more significant efficiency improvement and cost reduction," *International Journal of Production Research*, vol. 58, no. 10, pp. 2916–2936, 2020.

[5] C. Y. Medina, "Distribución de planta y mejora de procesos mediante el mantenimiento preventivo para aumentar la productividad en una empresa agroindustrial en el distrito de Chao, 2020," *Bachelor's Thesis*, Universidad Privada del Norte, 2022. [Online]. Available: https://hdl.handle.net/11537/

[6] I. N. Mendo, "Diseño de una distribución de planta para incrementar los niveles de productividad en la empresa Inversiones Cimas E.I.R.L.," *Bachelor's Thesis*, Universidad Privada del Norte, 2021. [Online]. Available: https://hdl.handle.net/11537/27460

[7] R. Muther, *Planning and Projection of the Industrial Company (SLP Method)*. Barcelona, Spain: Técnicos Asociados S.A., 1968.

[8] C. A. Rincón and F. Villareal, *Costos: Decisiones Empresariales*. Bogotá, Colombia: ECOE Ediciones, n.d. [Online]. Available: https://www.ecoeediciones.com/wp-content/uploads/2015/09/Costos-decisiones-empresariales.pdf

[9] A. Suñe, F. Gil, and I. Arcusa, *Practical Manual for the Design of Production Systems*, 1st ed. Madrid, Spain: Díaz de Santos, 2004.

[10] R. C. Vaughn, *Introduction to Industrial Engineering*, 2nd ed., 1990, p. 111.

[11] R. Gutierrez and R. de la Vara, *Control Estadístico de la Calidad y Seis Sigma*. Mexico City, Mexico: McGraw-Hill Interamericana, 2013.