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Tesis

Optimization of plant design in a pharmaceutical industry company: systematic layout strategies and performance evaluation

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Optimization of Plant Design in a Pharmaceutical Industry Company: Systematic Layout Strategies and Performance Evaluation

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Abstract. The research at Quimivet S.A. revealed an inefficient plant design, with significant downtime in transportation due to poor area distribution. This affects operational efficiency and underscores the need for strategic redistribution to optimize workflow and reduce idle times. The study focused on plant layout, aiming to reduce travel distances and production times using the Systematic Layout Planning methodology and Layout Performance Index. Tools used included the Process Analysis Diagram (DAP) for comparing times and distances before and after implementing the methodology, and Layout Performance Index Matrices (IDL) to calculate efficiency. The Relational Table helped determine area proximity, as well as the reasons behind the changes being made. The implementation resulted in a 5.6% reduction in operational times and a 46.57% decrease in travel distances. Layout management improved by 25.96%. This supports findings by Álvarez, De Ávila, and Hurtado [8], who concluded that Systematic Layout Planning minimizes delays and improves space efficiency.

Keywords. Layout performance index, plant distribution, evaluation of plant distribution, redistribution, Process Analysis Diagram, Pharmaceutical company.

1. Introduction

The company Quimivet S.A. operates in the veterinary medicine production sector, a field that has seen significant growth in Peru in recent years, driven by the livestock industry. In 2020, Peru exported veterinary medicines worth \$22.6 million, an increase of 6.5% compared to the previous year [1]. That same year, the global veterinary medicine market was valued at \$427,910.6 million, representing a 4.8% growth compared to the previous year. Additionally, the United States was the world's largest buyer, acquiring 18.6%, or \$79.7 billion, of the total market, followed by Germany with \$33.6 billion, and Switzerland in third place with \$26.6 billion [1]. Among the most notable suppliers were Germany, Switzerland, and Belgium. Furthermore, Peru ranked 77th worldwide and 10th in Latin America, below countries like Chile and Uruguay [1].

Plant layout refers to the physical and strategic arrangement of equipment involved in the manufacturing process. This reorganization emerges as a response to a previously inadequate layout, which hinders the achievement of the industry's established goals [6].

The Systematic Layout Planning (SLP) method is a structured approach that facilitates planning the layout of a plant. It is a tool that enables the efficient use of resources, organization of work areas and industrial equipment, and optimization of processes. It also contributes to enhancing competitiveness and fostering continuous improvement, as the method includes not only a quantitative analysis of the plant's dimensions but also a qualitative evaluation of the relationships between areas, material flow, employee comfort, and specific process and storage requirements. Additionally, SLP is recognized as the most widely used and accepted methodology for solving problems in industrial plant layouts [7]. The SLP method provides clear evidence of how an appropriate plant layout can reduce costs, minimize waste, and increase competitiveness in the market for alternative materials, achieving greater efficiency and sustainability [7].

On the other hand, the Layout Performance Index (IDL) method aims to systematically evaluate the spatial layout of the plant by quantifying key elements affecting productivity. It is based on identifying the transport intensities between activity centers, creating a transport matrix that is simplified to summarize flows. It uses indices such as the Operational Flow Index (IFO) and the Subjective Relationship Index (IFS) to measure transport efficiency and the desired proximity between areas. The IDL calculation integrates qualitative and quantitative

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analyses to assess the performance of the current design. Expected outcomes include a redistribution that reduces distances and transport times, increases productivity, and optimizes space utilization [2].

2. Methodology

The research methodology is essential for this article, as a mixed approach is adopted, combining quantitative and qualitative methods. This approach involves conducting surveys and interviews evaluated using a measurable scale and assigned numerical values, along with mathematical calculations to measure parameters [10]. The objectives were achieved through a series of steps: a visit to the plant was carried out to identify its main problem and access reports such as blueprints; a Process Activity Diagram was used to diagnose the company by focusing on key aspects; the Layout Performance Index was calculated to determine the current layout's efficiency; the Systematic Layout Planning method was applied, including steps to develop a relational table; and the company's proposed Layout was designed using the Systematic Layout Planning (SLP) method. Finally, a DAP and a final IDL analysis were conducted to evaluate the effectiveness of the SLP method, as these analyses are characterized by their use of indicators and timing evaluations.

3. Current Layout

This section presents the company's current layout, showing work areas with excessive space relative to their productive value. For instance, during the plant visit, it was noted that the dressing room area has unnecessary empty space, which does not contribute to the company. In contrast, the sealing area has limited workspace due to the machines, making operations difficult in that area. Figure 1 shows the current layout in more detail.

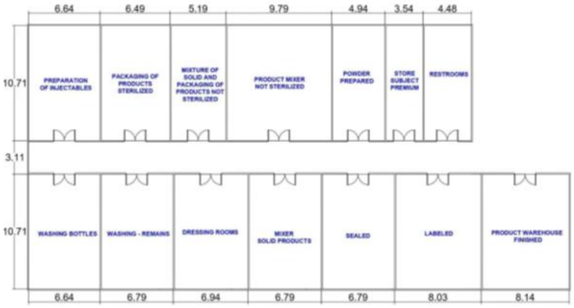
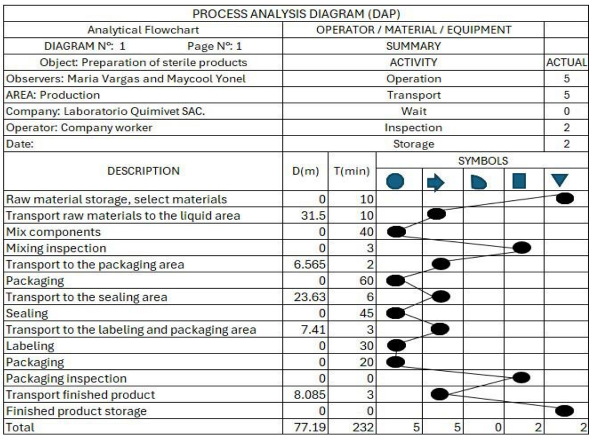


Figure 1. Company's Current Layout

4. Identification of the Process Activity Diagram

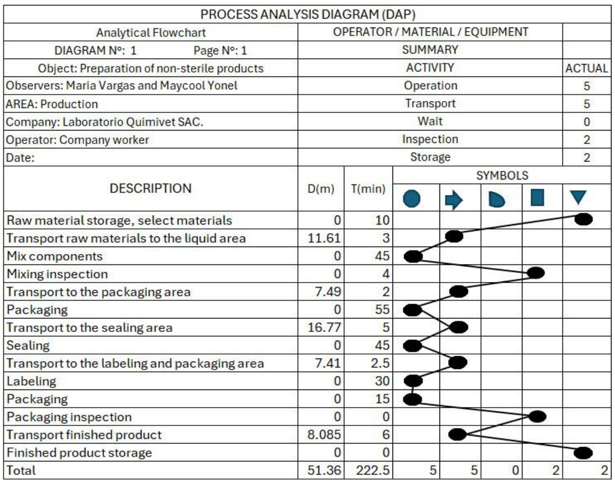
At Quimivet, pharmaceutical products are produced in sterile and non-sterile areas. Sterile products, such as injections and intravenous solutions, require strict conditions to avoid microorganisms, while non-sterile products, intended for external or less invasive applications, only require basic hygiene standards. For this reason, two process activity diagrams were created, differentiating the specific requirements and steps for the production of sterile and non-sterile products. To measure productivity, observation and activity measurement methods have been used, evaluating production time and the distances traveled. Figures 2 and 3 show the process analysis diagrams for sterile and non-sterile products, respectively.



PROCESS ANALYSIS DIAGRAM (DAP)		
Analytical Flowchart	OPERATOR / MATERIAL / EQUIPMENT	
DIAGRAM Nº: 1 Page Nº: 1	SUMMARY	
Object: Preparation of sterile products	ACTIVITY	ACTUAL
Observers: Maria Vargas and Maycool Yonel	Operation	5
AREA: Production	Transport	5
Company: Laboratorio Quimivet SAC.	Wait	0
Operator: Company worker	Inspection	2
Date:	Storage	2

DESCRIPTION	D(m)	T(min)	SYMBOLS				
			●	➡	◗	■	▼
Raw material storage, select materials	0	10					●
Transport raw materials to the liquid area	31.5	10		●			
Mix components	0	40	●				
Mixing inspection	0	3				●	
Transport to the packaging area	6.565	2		●			
Packaging	0	60	●				
Transport to the sealing area	23.63	6		●			
Sealing	0	45	●				
Transport to the labeling and packaging area	7.41	3		●			
Labeling	0	30	●				
Packaging	0	20	●				
Packaging inspection	0	0				●	
Transport finished product	8.085	3		●			
Finished product storage	0	0					●
Total	77.19	232	5	5	0	2	2

Figure 2. Current process activity diagram for sterile products



PROCESS ANALYSIS DIAGRAM (DAP)		
Analytical Flowchart	OPERATOR / MATERIAL / EQUIPMENT	
DIAGRAM Nº: 1 Page Nº: 1	SUMMARY	
Object: Preparation of non-sterile products	ACTIVITY	ACTUAL
Observers: Maria Vargas and Maycool Yonel	Operation	5
AREA: Production	Transport	5
Company: Laboratorio Quimivet SAC.	Wait	0
Operator: Company worker	Inspection	2
Date:	Storage	2

DESCRIPTION	D(m)	T(min)	SYMBOLS				
			●	➡	◗	■	▼
Raw material storage, select materials	0	10					●
Transport raw materials to the liquid area	11.61	3		●			
Mix components	0	45	●				
Mixing inspection	0	4				●	
Transport to the packaging area	7.49	2		●			
Packaging	0	55	●				
Transport to the sealing area	16.77	5		●			
Sealing	0	45	●				
Transport to the labeling and packaging area	7.41	2.5		●			
Labeling	0	30	●				
Packaging	0	15	●				
Packaging inspection	0	0				●	
Transport finished product	8.085	6		●			
Finished product storage	0	0					●
Total	51.36	222.5	5	5	0	2	2

Figure 3. Current process activity diagram for non-sterile products

5. Calculation of the Current Layout Performance Index

5.1. Identification of the transport intensities in the company's activities

In this stage, the total transportation intensity between the different areas of the company is measured in liters per month (l/m). The amount of materials flowing between the activity centers is not uniform [2].

5.1.1. Identify the activity centers of the organization

Through data collection and direct observation at the plant's facilities, 14 activity centers were identified.

- ○ Finished Product Warehouse
- ○ Restrooms and Changing Rooms
- ○ Raw Material Warehouse
- ○ Labeling
- ○ Powder Preparation
- ○ Sealing
- ○ Liquid Mixer
- ○ Mixer and Equipment
- ○ Solid Mixer and Packaging
- ○ Changing Rooms
- ○ Sterilization
- ○ Equipment Washing
- ○ Injectable Preparation
- ○ Bottle Washing

5.1.2. *Directed square matrix of the partial transport intensities*

The process determines the material flow relationships between 14 activity centers. Then, a matrix t is developed, gathering monthly information about the amount of material in circulation in the production of QUIMIVET products. The matrix is constructed by evaluating the data for each product and linking the activity centers that transform or modify the raw material [2]. Figure 4 below shows the matrix t.

$$t= \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 718 & 0 & 0 & 0 & 0 & 0 & 908 & 0 \\ 1626 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1626 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 718 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1626 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 908 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure 4. Directed square matrix of the partial transport intensities

5.1.3. *Undirected triangular matrix of the total transport intensities (matrix T)*

The objective is to calculate the total transport flow between each pair of activity centers in both directions. To do this, it is considered that Tji = tij + tji. The result is a symmetric triangular matrix that represents the total transport intensities, also known as matrix T [2]. The matrix T is shown below in Figure 5.

$$T= \begin{bmatrix} 0 & 0 & 0 & 1626 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 718 & 0 & 0 & 0 & 0 & 0 & 908 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1626 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1626 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 718 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 908 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure 5. Undirected square matrix of the total transport intensities

5.2. *Identify the ideal qualitative adjacency relationships between activity centers*

Once information has been gathered about the activity centers that make up the production process of the company, the study is complemented with the analysis of the qualitative relationships between these centers.

5.2.1. *Select experts in the processes and operations of the organization under study*

To select the experts who will participate in the qualitative research, the intervention of the production manager is required, who guides the selection of workers based on their work experience, knowledge of the processes, and responsibilities during their shift. Although most workers have experience, a small group directly supervises and evaluates the execution of the work [2].

5.2.2. *Develop the triangular matrix of the ideal qualitative adjacency relationships (Matrix R)*

After surveying 10 plant operators, the data is tabulated using an ordinal scale. This scale allows for the identification of design problems from the perspective of the more experienced workers. Below, in table 1, is a summary of the data obtained from the questionnaire, where E = extremely important, I = important, O = ordinarily important, D = indifferent, N = undesirable [2].

Table 1. Summary of the procedure to obtain qualitative adjacency relationships through expert judgment

Activity Centers	**Ideal Adjacency Relationships**	**Mode**	**Rij**	**Justification**

I	J	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10			
1	2	N	N	D	N	N	D	D	N	N	N	N	-10	Increases the risk of contamination and downtime.
1	4	I	E	E	E	I	E	E	E	I	E	E	10	Operational efficiency and workflow continuity are maintained.
2	3	I	I	E	E	E	E	E	I	I	E	E	10	Facilitates quick access to hygiene and changing rooms.
3	4	O	O	O	O	O	O	I	D	O	D	O	2	Direct coordination is implemented in product storage.
3	5	N	N	N	D	D	D	N	N	N	N	N	-10	Prepared powders come into contact with unprocessed materials.
4	6	E	I	O	E	E	E	O	I	E	E	E	10	Labels are immediately applied and sealing is performed.
5	7	N	N	N	D	N	D	O	N	N	d	N	-10	Interference between the flows of these materials.
6	7	O	I	I	I	I	I	D	O	I	I	I	5	Reduces waiting times and improves synchronization.
6	8	I	O	I	I	I	I	O	I	I	O	I	5	Reduces the traveled distance, improving efficiency.
6	9	I	E	E	E	E	I	O	E	E	I	E	10	Minimizes errors and ensures product quality.
7	9	E	E	E	I	E	O	E	E	I	E	E	10	Precise control is maintained over mixing and packaging.
8	9	I	D	D	D	I	I	I	I	I	O	I	5	Monitors and adjusts mixing parameters.
9	11	N	O	I	N	O	O	O	O	D	N	O	2	Efficiency is ensured in workflow and material safety.
9	12	N	I	O	O	N	O	O	O	N	O	O	2	Ensures no transfer of unwanted microorganisms.
10	12	N	O	D	D	D	N	N	N	I	O	N	-10	Interference between employees changing and those handling dirty equipment.
11	12	O	D	D	O	N	I	I	I	I	I	I	5	Optimizes workflow and saves resources.
11	13	E	I	I	E	E	E	E	E	I	I	E	10	Injectable medicines are free from microorganisms.

11	14	I	E	I	E	I	I	I	O	O	I	I	5	Significantly reduces contamination risk.
12	13	O	I	I	O	E	O	O	I	O	O	O	2	Contributes to safety, efficiency, and compliance.
12	14	O	O	I	E	I	I	O	I	O	O	O	2	Adjacent areas reduce the distance and time needed to transport items.
13	14	O	I	I	O	E	O	O	I	O	E	O	2	Tasks are performed more efficiently, avoiding duplication of efforts.

After obtaining the evaluations from the experts for each qualitative adjacency relationship between the activity centers, the matrix R is created, which incorporates the parameterization of the survey data collected for each evaluated activity center [2]. Next, Figure 6 shows the matrix R.

$$R=\begin{bmatrix}
0 & -10 & 0 & 10 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 10 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 2 & -10 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 10 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -10 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 5 & 5 & 10 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 10 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 5 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 2 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -10 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 5 & 10 & 5 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 2 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

Figure 6. Triangular matrix of the ideal qualitative adjacency relationships

5.3. Identify the adjacency relationships of the current spatial distribution (Matrix X)

The matrix X is obtained through the assessment of the adjacency relationship between the activity centers involved in the production system. This matrix represents the adjacency relationships between these centers according to the current spatial distribution. In other words, it reflects how the centers are connected within the system. If there is a direct connection between two centers, the value is 1; otherwise, it is 0 [2]. Next, Figure 7 shows the matrix X.

$$X=\begin{bmatrix}
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

Figure 7. Adjacency relationships matrix of the current spatial distribution

5.4. Determine the relative level of importance of quantitative criteria versus qualitative criteria

In this stage, a value of α (alpha) equal to 0.75 is established for the production system, giving more weight to the transportation intensities between the activity centers. The results will be analyzed with a focus on the adjacency of the centers and their transportation intensity [2].
Determine the Layout Performance Index (IDL)
It is given by the following formula:

$$IDL = \frac{\alpha \cdot Ifo + (1-\alpha) \cdot Ifs}{100} \qquad (1)$$

5.5. *Finding the Operating Flow Index (IFO):*

To calculate the operating flow index, the upper triangular matrix T of available routes must be multiplied by the adjacency matrix X of current connections and divided by the summation of matrix T [2].

$$Ifo = \frac{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}(Tij \cdot Xij)}{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} Tij} \cdot 100\% \qquad (2)$$

The analysis reveals that the material transport between areas is not efficient, as the distance traveled is not minimized. With a value of 60%, lower than the required 75%, it shows that the current transport is far from the optimal situation according to the IFO. It is necessary to improve the distribution of connections between areas.

5.6. *Finding the Index of Subjective Relationships (IFS):*

To calculate the IFS, the matrix R (ideal relationships) is multiplied by the matrix X (current relationships) and the result is divided by the sum of the elements of the matrix R [2].

$$Ifs = \frac{\sum_{i=1}^{n-1}\sum_{j=l+i}^{n}(Rij \cdot Xij)}{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} Rij} \cdot 100\% \qquad (3)$$

The current layout of the plant is not the most suitable, as it does not meet the established minimum criteria. With a value of 51%, lower than the required 75%, it shows that the workers are not satisfied with the current setup and that the plant's efficiency could be improved.

5.7. *Calculation of the Layout Performance Index (IDL):*

Finally, obtaining the Layout Performance Index (IDL) allows for the evaluation of the current positioning of the spatial layout of the plant under study. The value of the IDL ranges between zero and one [2].

$$IDL = \frac{\alpha \cdot Ifo + (1-\alpha) \cdot Ifs}{100} \qquad (4)$$

The current design of the plant has a noticeable margin for improvement, as the current value of the indicator is only 57.72%, with potential for improvement of up to 42.28%. Improving this indicator will increase operational productivity, which will be reflected in shorter distances traveled and reduced production times.

6. Application of Systematic Layout Planning

Through this methodology, the goal is to improve the distances traveled and production times of the company. Next, the proximity values were determined, and the list of reasons was created to make the relational table.

6.1. *Proximity Value and List of Reasons*

The proximity value refers to the importance of adjacency that one area should have with respect to another. The classifications are as follows: A = Absolutely necessary, E = Especially necessary, I = Important, O = Normal or ordinary, U = Unimportant, X = Undesirable, and XX = Highly undesirable [4].

Regarding the list of reasons, it refers to the rationale for why one area should be close to another. The reasons considered, classified from 1 to 6, are as follows: 1 = Material flow, 2 = Reduction of material traffic, 3 = Cross contamination, 4 = Services for personnel, 5 = Excessive noise for personnel, and 6 = Quality verification.

6.2. *Relational Table*

Next, as shown in Figure 8, the relational table was created, taking into account the proximity values and the previously analyzed list of reasons. Notably, seven critical relationships were identified in which the areas must be in close proximity due to material flow requirements, highlighting the importance of these connections in the layout design.

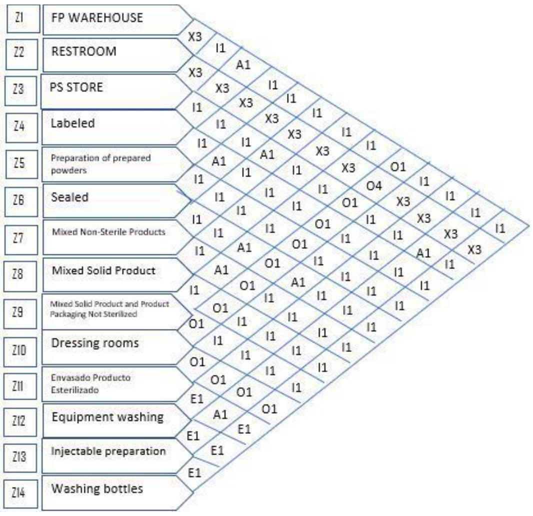


Figure 8. Relational Table

7. Proposed Layout

This section presents the Proposed Layout of the company, where a change in the order and dimensions of the work areas can be observed, in addition to prioritizing certain zones responsible for adding greater value to the final product. This design is based on the SLP (Systematic Layout Planning) method, through which the critical relationships between the different areas of the plant were identified and analyzed, enabling a redistribution that optimizes the flow of materials and reduces travel distances. Figure 9 shows the proposed layout in more detail.

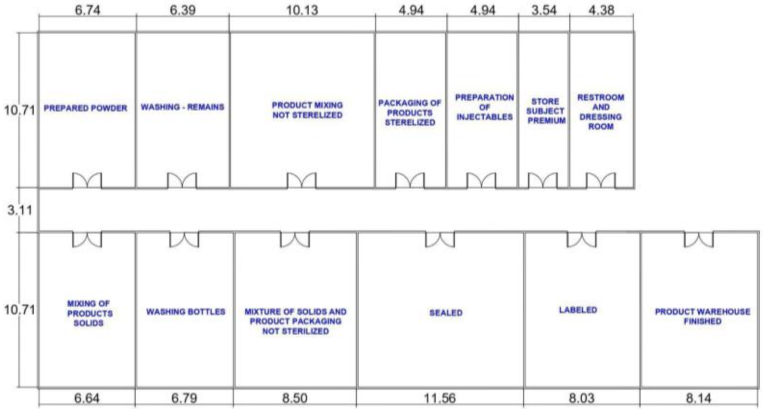


Figure 9. Company's Proposed Layout

8. Comparative Analysis

The proposal maintains three key matrices constant, representing different aspects of transportation and the ideal adjacency between areas. The t matrix of partial transportation intensities remains constant because the volumes of liters transferred between areas are conserved unchanged. Similarly, the T matrix maintains its structure, as it continues to be considered that Tji = tij + tji. Likewise, the R matrix, which is derived from the survey and represents the ideal connections between areas, also remains unchanged. In contrast, the X matrix, which reflects the adjacencies in the current spatial distribution, has been modified due to the Systematic Layout Planning (SLP) methodology, which reorganized the areas to optimize the space. Next, Figure 10 shows the new matrix X.

$$X=\begin{bmatrix}
0&0&0&1&0&0&0&0&0&0&0&0&0&0\\
0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&1&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1\\
0&0&0&0&0&0&0&0&0&0&0&0&0&1\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{bmatrix}$$

Figure 10. Matrix of adjacency relationships of the proposed spatial distribution

The application of the SLP methodology and the improvement of the layout performance index (IDL) have had a notable positive impact on the flow and relationship indicators, resulting in an increase in the Operational Flow Index (IFO), which rose from 60% to 82.34%, and the Subjective Relationship Index (IFS), which increased from 51% to 80%. These increases reflect an improvement in flow efficiency and in the satisfaction of proximity requirements between areas according to operational optimization criteria.

Finally, the combination of these factors has raised the Layout Performance Index (IDL), which was previously 57.72% and now reaches 83.68%. This result confirms that the proposal has significantly optimized the overall design performance, reducing transportation distances, improving accessibility, and the relationship between areas.

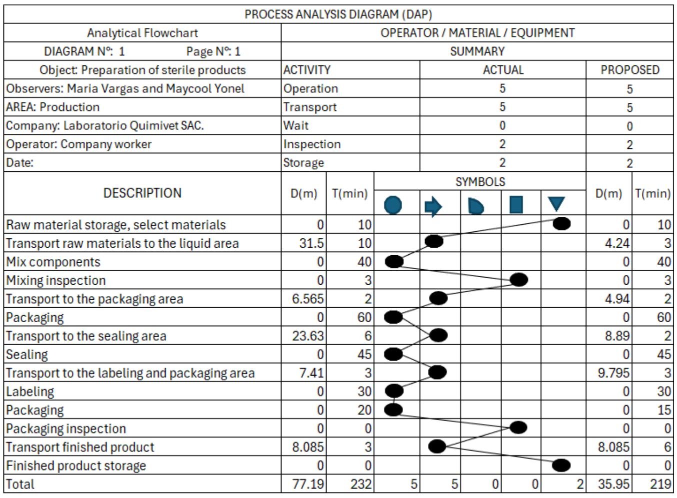
In conclusion, the applied methodology has allowed for the maintenance of constant partial and total transport intensities and ideal adjacency relationships, while also improving the real adjacency of areas and the design performance in both quantitative and qualitative terms. The improvement in the IDL is a direct reflection of this optimization, ensuring a more functional and efficient layout.

9. Proposed Process Activity Diagram

In the analysis and optimization of the Process Activity Diagram (DAP), significant improvements were achieved both in the efficiency of the distances traveled and in the processing times.

9.1. DAP of the sterile product

The distance traveled on the production line of these products is reduced from 77.19 meters to 35.95 meters, achieving a notable improvement that minimizes unnecessary movement and optimizes internal logistics. Likewise, the total processing time for sterile products decreased from 232 minutes to 219 minutes, a change that, although seemingly modest, reflects significant cumulative efficiency at each stage of the process. These improvements not only benefit daily operations but also enhance the factory's responsiveness to the growing demand for sterile products. Next, Figure 11 shows the new DAP for sterile products.

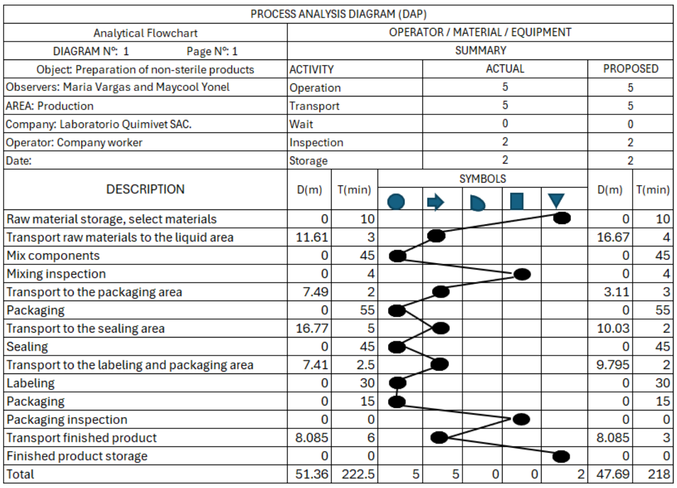


PROCESS ANALYSIS DIAGRAM (DAP)									
Analytical Flowchart	OPERATOR / MATERIAL / EQUIPMENT								
DIAGRAM N°: 1 Page N°: 1	SUMMARY								
Object: Preparation of sterile products	ACTIVITY		ACTUAL					PROPOSED	
Observers: Maria Vargas and Maycool Yonel	Operation		5					5	
AREA: Production	Transport		5					5	
Company: Laboratorio Quimivet SAC.	Wait		0					0	
Operator: Company worker	Inspection		2					2	
Date:	Storage		2					2	
DESCRIPTION	D(m)	T(min)	SYMBOLS					D(m)	T(min)
			●	➡	◗	■	▼		
Raw material storage, select materials	0	10					●	0	10
Transport raw materials to the liquid area	31.5	10		●				4.24	3
Mix components	0	40	●					0	40
Mixing inspection	0	3				●		0	3
Transport to the packaging area	6.565	2		●				4.94	2
Packaging	0	60	●					0	60
Transport to the sealing area	23.63	6		●				8.89	2
Sealing	0	45	●					0	45
Transport to the labeling and packaging area	7.41	3		●				9.795	3
Labeling	0	30	●					0	30
Packaging	0	20	●					0	15
Packaging inspection	0	0				●		0	0
Transport finished product	8.085	3		●				8.085	6
Finished product storage	0	0					●	0	0
Total	77.19	232	5	5	0	0	2	35.95	219

Figure 11. Proposed DAP of sterile products

9.2. *DAP of the non-sterile product*

The distance traveled in the production of these products was reduced from 51.36 meters to 47.69 meters, while the processing time decreased from 222.5 minutes to 218 minutes. Although these improvements are less pronounced compared to the sterile products, they represent an optimization that contributes to the efficiency of the production process. Next, Figure 12 shows the new DAP of non-sterile products.



PROCESS ANALYSIS DIAGRAM (DAP)			
Analytical Flowchart	OPERATOR / MATERIAL / EQUIPMENT		
DIAGRAM N°: 1 Page N°: 1	SUMMARY		
Object: Preparation of non-sterile products	ACTIVITY	ACTUAL	PROPOSED
Observers: Maria Vargas and Maycool Yonel	Operation	5	5
AREA: Production	Transport	5	5
Company: Laboratorio Quimivet SAC.	Wait	0	0
Operator: Company worker	Inspection	2	2
Date:	Storage	2	2

DESCRIPTION	D(m)	T(min)	SYMBOLS ●	➡	D	■	▼	D(m)	T(min)
Raw material storage, select materials	0	10					●	0	10
Transport raw materials to the liquid area	11.61	3		●				16.67	4
Mix components	0	45	●					0	45
Mixing inspection	0	4				●		0	4
Transport to the packaging area	7.49	2		●				3.11	3
Packaging	0	55	●					0	55
Transport to the sealing area	16.77	5		●				10.03	2
Sealing	0	45	●					0	45
Transport to the labeling and packaging area	7.41	2.5		●				9.795	2
Labeling	0	30	●					0	30
Packaging	0	15	●					0	15
Packaging inspection	0	0				●		0	0
Transport finished product	8.085	6		●				8.085	3
Finished product storage	0	0					●	0	0
Total	51.36	222.5	5	5	0	0	2	47.69	218

Figure 12. Proposed DAP of non-sterile products

10. Conclusion

In the comparative analysis of the Layout Performance Index between the current and proposed layouts, a notable improvement in key indicators is observed. The proposed layout optimizes the flow and proximity of work areas, increasing the Operational Flow Index from 60% to 82.34% and the Subjective Relationships Index from 51% to 80%. This reflects greater efficiency in material movement and better accessibility, reducing transportation times. This result is comparable to another study, where the IFO increased from 25.88% to 101.66%, while the IFS decreased from 24.39% to 19.51% [2].

The overall Layout Performance Index improved from 57.72% to 83.68%, demonstrating a more functional and efficient layout. This is attributed to the Systematic Layout Planning methodology, which reorganizes spaces to minimize distances and optimize resources. This result aligns with another study, as its application as a case study in a company from the metalworking sector allowed for the identification of improvement opportunities in spatial distribution amounting to 53.28% [3].

Regarding the Process Activity Diagram, the redesign reduced both the distance traveled and the processing time. For sterile products, the distance decreased from 77.19 meters to 35.95 meters, and processing time from 232 minutes to 219 minutes, improving daily efficiency and responsiveness to demand. This result is similar to another study, where the production time of poles was reduced from 456 to 413.2 minutes, as well as the displacement from 62.5 to 54 meters; these results were achieved after implementing improvements in the Process Activity Diagram [11].

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