UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

Mejora del proceso productivo para incrementar la producción y reducir desperdicios en la Panadería Duque

.

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HOJA DE CALIFICACIÓN
DE TRABAJO DE FIN DE CARRERA

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Improvement of the production process of Duque Bakery to increase production volume and reduce waste

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RESUMEN

Del año 2022 al 2023, la Industria Panadera y Pastelera tuvo un crecimiento de 6.8% de manera global. Se estima para que el año 2027 se llegue a una tasa de crecimiento anual compuesta del 6.0%, esto quiere decir ingresos de $305 billones (The Business Research Company, 2023). El pan ocupa un puesto elevado dentro de los alimentos más consumidos por parte de los ecuatorianos. Según el INEC (2019), aproximadamente el 18% del presupuesto para alimentos y bebidas es destinado únicamente para la compra de este tipo de alimentos. Panadería Duque, es una empresa pequeña que busca incrementar su volumen de producción para lograr satisfacer su demanda. La estrategia propuesta es el uso de la metodología DMAIC, con un enfoque hace la disminución de desperdicios, y un nuevo diseño de planta de producción. Mediante el uso de varias herramientas se analizan los procesos de producción, como los desperdicios generados dentro de ellos. De acuerdo con Shaker Abualsaud et al. (2019), muchas veces el diseño de planta no es realizado mediante un método científico, y es por esto, que se pasan por alto varios factores que conllevan a un diseño de planta pobre. Esto a su vez conlleva a tiempos de transporte altos, un uso de materiales y productos altos, y desaprovechamiento de recursos. Esta es una de las razones, por las cuales se considera importante analizar el *layout*, y el efecto que este tiene en la disminución de desperdicios. El plan final de la implementación incluye tres diseños de plantas propuestos (SLP, BLOCPLAN y LOGIC), junto con la evaluación de cada uno de ellos, realizadas con la calificación de adyacencia y los resultados de la simulación. El resultado es un *layout* eficiente que disminuye tiempos de proceso, eficiencia de los trabajadores, y un aumento en la producción. Asimismo, se incluye un plan de control frente a las mejoras propuestas.

Palabras clave: Panadería, DMAIL, Lean, Diseño de planta, Simulación

ABSTRACT

From 2022 to 2023, the Bakery and Pastry Industry had a global growth of 6.8%. It is estimated that by 2027, the industry will reach a compounded annual growth rate of 6.0%, which means revenues of $305 billion (The Business Research Company, 2023). Bread holds a high position among the most consumed foods by Ecuadorians. According to INEC (2019), approximately 18% of the budget for food and beverages is allocated solely for the purchase of this type of food. Duque Bakery is a small company that seeks to increase its production volume to meet its demand. The proposed strategy is to use the DMAIC methodology, with a focus on waste reduction and a new production plant design. By using several tools, the production processes are analyzed, including the waste generated within them. According to Shaker Abualsaud et al. (2019), plant design is often not carried out using a scientific method, which leads to several factors being overlooked, resulting in a poor plant design. This in turn leads to high transport times, high use of materials and products, and wastage of resources. This is one of the reasons why analyzing the layout and its effect on waste reduction is considered important. The final implementation plan includes three proposed plant designs (SLP, BLOCPLAN, and LOGIC), along with their evaluation, conducted using the adjacency rating and simulation results. The result is an efficient layout that reduces process times, worker efficiency, and increases production. Also, a control plan is included to address the proposed improvements.

Key words: Bakery, DMAIC, Lean, Layout Planning, Simulation

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INTRODUCTION

The global market of bread and bakery products has grown 6.8% from 2022 to 2023. For the year 2027, the compound annual growth rate is estimated to increase by 6.0% with an income of $304.89 billion (The Business Research Company, 2023). The bakery industry occupies an elevated position within the food consumption of the Ecuadorian population. According to INEC (INEC, 2023), Ecuadorians spend more than 18% of their food and beverage budget on the purchase of bread, cereals, and their derivatives. The percentage of consumption in Quito, capital of Ecuador, is over 20%. In Pichincha, according to the SRI, there are over 1.329 registered bakeries.

In the year 2019, the bread and bakery industries had an annual sale of USD 306 million according to the INEC. These businesses have also directly helped 13.407 people with employment. Ecuadorians consume twenty-seven kilograms of bread per habitant. There is the myth that the breath consumption is bad, however this food provides group B vitamins, minerals such as phosphorus, magnesium, and potassium. According to the World Health Organization (2018), it is recommended to consume 40 to 60 grams of bread at each meal, that is, 250 grams per day. With this value of daily consumption, it can be said that between 80kg and 90kg per year per inhabitant should be consumed. Hence, it translates to an opportunity for the bread and bakery industry as they can keep growing and developing.

Duque Bakery is a small-sized company that started as a small family business in 1998 in El Quinche, Ecuador. It started with two employees and one location. By 2017, it had over fifty employees and 7 different bakeries located in various sectors of the province of Pichincha. Unfortunately, the owners had to close their business due to personal circumstances. In 2021, one of the owners decided to reopen their first location and start over with the business. Now they have seven active employees and are planning to expand and open more bakeries.

With the constant growth of the bakery business, Duque Bakery must stand out, not just with their prices but also with the variety and quality of the products. At the moment, they offer a total of twenty-nine distinct products, of which fourteen are bakery products, nine are pastry products and the rest are externally manufactured products. Over the course of the last year, it increased their sales on 90% and produced 488 breads per day. With the increase on demand, Duque Bakery *could not satisfy it* because of their limited resources. In addition, with non-standardize processes, their production times are long and have a lot of waste activities. All these factors affect their production and sales volume.

According to Shaker Abualsaud et al. (2019) in many industries the plant layout is not constructed based on scientific methods. The design depends on serious factors such as an increasing demand, the space available, machines, how much experience the people making the decision have. All of them can result on a poor layout design, where the traveling time and use of materials and products is high.

Our main goal is to analyze the production process, movements, and layout design of Duque Bakery in order to minimize waste in movements and transportation, while increasing production volume. For this study, the DMAIC methodology is being utilized. It has been shown that this methodology allows for waste minimization and finding viable solutions by transforming large problems into smaller and more manageable ones (Belén et al., 2021).

LITERARY REVIEW

A well-designed bakery layout can impact the success of a business. It can not only enhance the overall customer experience but also improve productivity and efficiency. In this work we apply Lean Manufacturing, SLP planning and Material handling. All these concepts are crucial components that collaborate to achieve continuous improvement. Therefore, in this section each of these concepts are introduced.

Lean Manufacturing

Lean Manufacturing comes from the Theory of Toyota Production System, which was introduced by Taiichi Ohno. In the last years, this system has been implemented in many successful industries and organizations around the world. The results from Lean Manufacturing have had a positive impact in different sectors. Moreover, the results cannot only be seen in the performance of the processes, but in the customer satisfaction, lead time and waste reduction in general (Chiarini et al., 2018). In 2002, Xerox Corporation combined Lean and Six Sigma methodologies and named it “Lean Six Sigma”, they wanted to improve the product production process well as reducing costs and eliminating errors (Ahmed et al., In 2002, Xerox Corporation combined Lean and Six Sigma methodologies and named it “Lean Six Sigma”, they wanted to improve the quality of the production process, as well as reducing costs and eliminating errors (Ahmed et al., 2018).

Lean Six Sigma can help the companies gain more customers by focusing on the reduction of variation from service, design process, and manufacturing, also by the elimination of waste. When applied correctly these tools can help businesses achieve a competitive advantage in the marketplace. Lean Six Sigma guides the improvement process by implementing the DMAIC methodology (Purdue University, 2021).. DMAIC is a well-defined problem-solving method, where each phase builds on the prior one. The phases are define, measure, analyze, improve, and control. They all work together with the goal of implementing long-term solutions to the problems defined on the first stage (Berardinelli, 2016).

Layout Planning Algorithms

The generation and evaluation of a number of layout alternatives is a critical step in the facilities planning process, since the layout selected will serve to establish the material flow patterns and physical relationships between activities (Tompkins et al., 2010). Facility layout design has a major influence on plant productivity. The purpose of layout design is to find the most effective facility arrangement and minimize the material handling (Ali Naqvi et al., 2016). *Procedures for developing layout alternatives can be classified into two categories: improvement and construction, depending on whether the goal is to build a new facility from scratch or to improve an existing design at a facility* (McKendall & Hakobyan, 2021).

Prior to making any changes to the facility layout, it is important to assess the long-term effects of the changes. The new layout should make the costs associated with moving machines or departments justifiable (Ali Naqvi et al., 2016).

Layout optimization methods and tools: A systematic literature review (Stelle Chemim et al., 2021) shows us that the primary method of organizing layout in a facility is Systematic Design Planning (SLP). It combines tools related to the process, the products, and the ergonomic aspects of the production system. Another approach for facility layout design is BLOCPLAN, In the study *Production Facility Design Improvement with BLOCPLAN Algorithm* the BLOCPLAN algorithm proved to be an effective method of production layout problems. The results of the study showed that there was a reduction of moment displacement after BLOCPLAN algorithm improvement(Siregar et al., 2020). In the paper *Improved Effective Capacitance Computations for Use in Logic and Layout Optimization* a new algorithm for solving the two-dimensional guillotine cutting problem using LOGIC is presented. The proposed algorithm is based on a logarithmic scaling of the objective function and shows better performance compared to other state-of-the-art methods (Kahng & Muddu, n.d.).

Material Handling

The material handling system is a crucial tool for facility design because it helps to understand material flow and makes suggestions for better departmental layouts within the facility. The correct quantity, condition, place, position, sequence, and costs of materials are provided by the material handling system, which is visible in daily activities (Tompkins et al., 2010).

Within material handling, in the food industry, the safety of managing the ingredients must be considered. In the food industry, quality assurance (QA) systems are applied to ensure food safety and food quality to prevent liability claims and to build and maintain trust of consumers. To improve quality management and to assure food production quality in thebakery sector, four QA systems are used: (I) the Hygiene code for bread and confectionery, (2) HACCP (Hazard Analysis Critical Control Points), (3) ISO 9000-series (International Organization for Standardization), and (4) BRC (British Retail Consortium). (Van Der Spiegel et al., 2005).

SLP as a tool in DMAIC methodology

In 2019, Shaker Abualsaud et al. applied DMAIC and SLP in the improve phase and demonstrated that this methodology was effective in identifying problems and creating efficient layout designs. They achieved their goal of reducing total cost, travel distance, and operation time, while maximizing safety and efficiency, by analyzing and measuring factory processes to find the best combination layout. As a result, layout design efficiency was greatly improved, increasing from 52% to 91%. Additionally, the chosen layout design guarantees higher production rates and improved efficiency (Shaker Abualsaud et al., 2019).

A case study on using evolutionary algorithms to optimize bakery production planning this paper presents a case study on the optimization of the layout of a bakery using simulation and optimization techniques (Hecker et al., 2013). The authors use a simulation model to evaluate the performance of different layout configurations and optimize the layout based on criteria such as throughput time, resource utilization, and product quality. After the implementation of the new proposed layout an evident improvement was reflected on the production volume, material handling as well as a decrease of wastes.

Khaled and Mapa (2012) point out that the arrangement of machines, people, and materials is a crucial factor that is directly related to future capital investment, productivity, and an efficient working environment. Small and medium-sized enterprises, such as bakeries, often overlook the issue of poor layout design. This is due to their low production levels, and the fact that the problem is usually hidden within the process and is rarely visible to people. This results in generating obstacles to the productivity of operators. Moreover, it is mentioned that a good plant design within a bakery can simplify the process, decrease material handling costs, eliminate non-value-adding activities, and lead to efficient space utilization.

METHODOLOGY

Process improvement occurs most effectively on a project-by-project basis. DMAIC is a structured five-step problem-solving procedure that can be used to successfully complete projects by proceeding through and implementing solutions that are designed to solve root causes of quality and process problems, and to establish best practices to ensure that the solutions are permanent and can be replicated in other relevant business operations (Douglas C. Montgomery, 2009).

Define

Planning is the key to the first stage of any project. A project charter (Gido et al., 2018) is an excellent tool to keep track of the requirements, goals, and execution. Moreover, determining the baseline or current state of the project is also important for understanding how the process is evolving through the various phases(Starns, 2019) tools that were used to determine this were Gemba Walk, Gantt Diagram and even interviews with managers, owners, and workers.

Measure

This next phase we primarily focused on data collection. Once we recollected the times associated with each activity within the process in the next phase different tools would be used to analyze it. Furthermore, financial information will be gathered to comprehend the connection between waste and the company's monetary impact (Hofer et al., 2012).

Analyze

During this phase we will use various tools to analyze the data, some of those tools are value stream map (VSM) that will be used to determine the activities that do not add value to the final product (Kharub et al., 2022). A spaghetti diagram is also used, this will help us to track the movements from start-to-end process. According to Senderska, et al. (2015), this is a useful tool that, by focusing on people as a factor affecting productivity, leads to the need to find options that optimize workers' activities. Additionally, it allows for clear identification of inefficient movements and areas, enabling changes to be made within work areas and their layout. As an additional tool we will use the Ishikawa Diagram to analyze the results found with the tools mentioned before.

It should be noted that within this phase, each of the activities carried out by the operators was also classified into 5 categories. The first category is processing, which includes all types of actions carried out to produce or make the dough. The second is inspection, which includes activities where verification or checking is done. Then there is transportation and movement, where the difference between them is that in transportation, the operator is carrying or moving materials or tools, while in movement, the operator is not carrying anything. Finally, retention refers to when the process has to stop or wait until another activity is completed.

It was decided to calculate the percentage of the productive and unproductive activities that existed within the production processes of Duque Bakery. For this, the formulas recommended by Asalde (2017) was used, which are the following:

$$\%\, Productive\ Activities = \frac{sum\ of\ times\ of\ productive\ activities}{sum\ of\ total\ time\ of\ activities}\ x\ 100$$

$$\%\, Unproductive\ Activities = \frac{sum\ of\ times\ of\ unproductive\ activities}{sum\ of\ total\ time\ of\ activities}\ x\ 100$$

Improve

There are two important parts to the improvement phase: Improving the process itself and validating its proposals (Socconini, 2020). Implementation time, cost and available resources should be considered to suggest improvements that are feasible for the company (Pyzdek & Keller, 2010). The main tool we implement to improve the process is a redesign layout using different approaches sucha as SLP, BLOCKPLAN and LOGIC. Later, we analyzed the proposed layouts using both adjacency rating and simulation. A simulation will help us for the improvement validation in order to better understand the internal process flow, and if it is the case, find any issue like bottles necks, etc. By the application of the best for the proposed layout design of an optimized plant, we were able to reduce the waste due motion and transportation, therefore increasing the productivity of the plant (Wiyaratn et al., 2013).

Control

In this stage, the improvements previously implemented must be controlled and followed up so that the company remains in a process of continuous improvement (Socconini, 2020). The main tool used in this phase is a control plan that allows long-term stability in the execution of redesigned activities(Srinivasan et al., 2016). The tool consists of a list of activities that an organization should perform to standardize processes and minimize deviations. The tool also provides documented evidence that can be used in future projects.

RESULTS

Define

The Define phase, which is the first phase of our project, began by gathering as much information as possible about the current state of the company. This was done to gain a clear understanding of all the processes in place within the company and identify areas or activities that require improvement. First, a project charter was created to establish goals, responsibilities, resources, timelines, and other key elements (as shown in Figure 1). This is an excellent tool to track requirements, objectives, and execution throughout the various project phases(Gido et al., 2018).

Figure 1. Project Charter

Project Charter

Business

Panaderia Duque generates waste on their productions processes of bakery and pastry, these wastes are: unnecessary movements which causes loss of time due to the lack of adequate space.

Objectives

Reduce movements and transportation

Decrease production time

Incresea production volume

Goal Statement

Analizar el proceso de producción y el layout para poder disminuir tiempos de espera, incrementar volumen de producción y reducir desperdicios de movimientos

Timeline

Phase	Planned Completion Date	Actual
Define:	08/02/2023	-
Measure:	25/02/2023	-
Analyze:	06/03/2023	-
Improve:	22/03/2023	-
Control:	19/04/2023	-

Team Members

Position	Person	Title	Mobile Number
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Resources

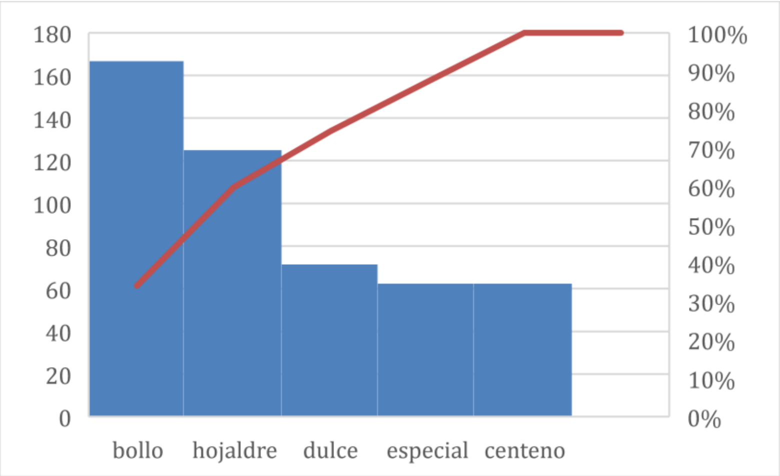
Historical sales information

Contact with the owner of the bakery

Access to the production plant

As we gathered information about the bakery products, we decided to group them by dough/product family, based on research indicating that this strategy can simplify the complexity of the processes (Zhang & Liberatore, 2004). Specifically, we classified the bakery products into five families: bun (bollo), puff pastry (hojaldre), sweet (dulce), special (especial), and rye (centeno). To identify the product families that contributed the most to the company's sales, we used a Pareto diagram, as recommended by Tian et al. (2018). The analysis revealed that the top three sales-contributing families were bun (bollo), puff pastry (hojaldre), and sweet (dulce), as shown in Figure 2. On the other hand, the company only produces one type of dough for its pastry product. Therefore, we will gather information about the time it takes to prepare each of the doughs mentioned before.

Figure 2. Pareto Bakery Product Families



An important tool implemented during this phase was Gemba Walk, it is important because it provided a direct and firsthand view of the work being done and help to identify problems that may not be visible from a distance or through reports (Dalton, 2019). As we carried out the Gemba walk we could observe that the plant has a lack of material organization, a large amount of distance between the raw materials and the pastry area, unnecessary movements within the processes, lack of compliance with food safety, a narrow warehouse, and an undetailed production schedule.

Finally, Interviews were done, this are an effective way to obtain rich and detailed information about human experience, and they can help identify problems and challenges in different areas (Kvale & Brinkmann, 2009). During the interviews conducted with both the owners and all the employees, they identified the bottleneck as the warehouse. This was particularly evident when both bakery and pastry processes were carried out simultaneously, and employees had to remove items, resulting in minor collisions. Furthermore, they identified the best improvement opportunities within the pastry processes, and their goal was to expand their production plant to meet the increased demand.

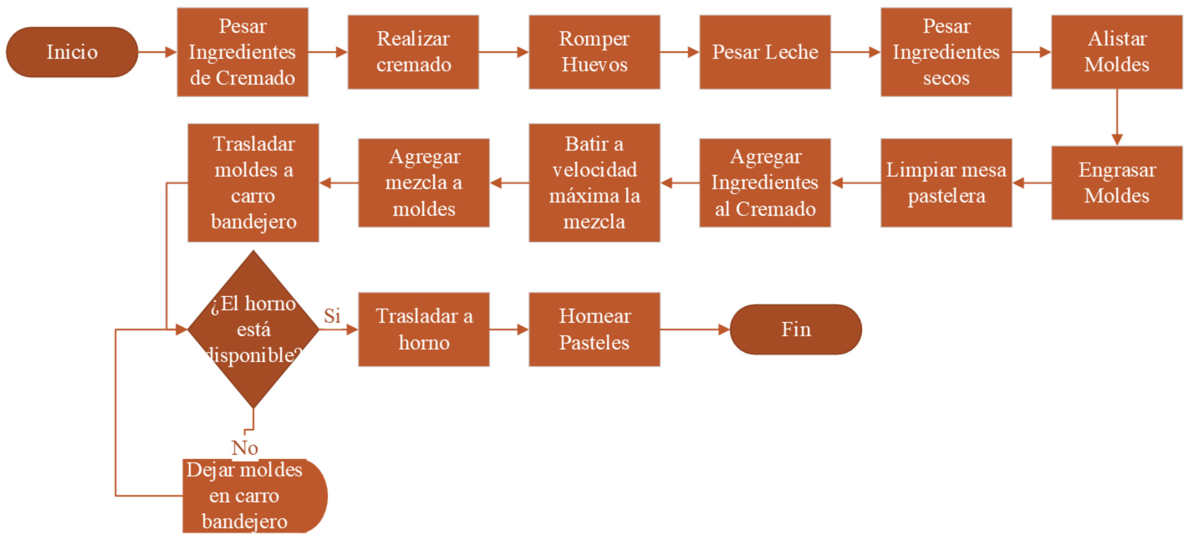
Based on the information gathered, we can see that Duque's Bakery has experienced significant growth, increasing its sales by more than 90% from 2021 to 2022. However, the increased demand has also led to longer processing times and wasted movements, which are negatively impacting their production volume and sales.

Measure

The main objective of the following phase was to understand how the processes work and identify the method for data collection, as suggested by Carreira (2006). To achieve this, we started by mapping the processes involved in both bakery and pastry production. It was observed that all the doughs used in bakery production involved the same set of activities, as shown in Figure 3. The activities carried out for the pastries process are the ones shown in Figure 4.

Figure 3. Process mapping for bakery dough

Figure 4. Process mapping for pastries dough



Once we knew all the activities involved in the production process of both bakery and pastries, we determined how many observations should be made per dough. Due to the fact that the production within Duque Bakery is a workshop-style production, where one person performs all activities in sequence to obtain the final product and considering that the elaboration of bread dough takes around 95 minutes and pastry elaboration takes around 84 minutes, based on Nibbel's recommended number of observation cycles, it is recommended to carry out 3 observations (Niebel et al., 2009). We will be collecting observations about the three doughs of bakery products that count for most of the sales for this area and the main dough for the pastry's products. According to Ferreira, conducting a time and motion study in a bakery can significantly improve efficiency and production planning, leading to greater profitability and customer satisfaction (Ferreira, T. H, et al., 2019).

Once we gathered the observations from each dough (Tables 1-2), we found that on average it takes approximately 98 minutes to make sweet (dulce) dough, and 97 minutes for bun (bollo) and puff pastry (hojaldre) dough. Additionally, it takes 99 minutes to prepare the dough for pastries. These time observations will help us as we implement the simulation and serve as a baseline to evaluate the effectiveness of our changes.

Table 1. Observations for bakery doughs

	HOJALDRE			ESPECIAL			DULCE		
PASOS	Tiempo 1	Tiempo 2	Tiempo 3	Tiempo 1	Tiempo 2	Tiempo 3	Tiempo 1	Tiempo 2	Tiempo 3
Pesar materia prima para masa	0:07:16	0:06:57	0:07:11	0:11:43	0:10:58	0:11:02	0:06:45	0:05:51	0:04:58
Amazar en mezcladora	0:04:36	0:03:55	0:03:26	0:05:42	0:04:58	0:05:36	0:03:31	0:05:25	0:04:28
Amazar a mano	0:05:27	0:04:58	0:05:14	0:07:22	0:06:58	0:06:47	0:12:27	0:14:11	0:12:34
Pesar masa	0:01:47	0:02:11	0:01:57	0:03:40	0:03:58	0:04:01	0:02:15	0:03:28	0:02:27
Labrar masa	0:07:03	0:06:52	0:07:11	0:08:46	0:07:58	0:07:42	0:07:56	0:07:31	0:06:47
Cortar masa	0:08:11	0:08:57	0:08:33	0:03:15	0:02:58	0:03:27	0:01:57	0:01:21	0:01:43
Dar forma de pan	0:10:06	0:10:57	0:10:33	0:05:48	0:05:54	0:06:12	0:07:56	0:08:11	0:07:25
colocar pan en bandejas	0:01:45	0:01:37	0:01:56	0:01:35	0:01:32	0:01:47	0:01:15	0:01:21	0:01:17
trasladar a camara de leudo	0:00:00	0:00:00	0:00:00	0:00:31	0:00:28	0:00:27	0:00:20	0:00:34	0:00:27
fermentar panes	0:15:00	0:15:00	0:15:00	0:30:00	0:30:00	0:30:00	0:30:00	0:30:00	0:30:00
Trasladar a horno	0:00:31	0:00:37	0:00:42	0:00:24	0:00:31	0:00:27	0:00:21	0:00:24	0:00:22
hornear pan	0:20:00	0:20:00	0:20:00	0:20:00	0:20:00	0:20:00	0:20:00	0:20:00	0:20:00
Sacar producto terminado	0:01:58	0:02:21	0:02:09	0:00:36	0:00:28	0:00:32	0:00:32	0:00:41	0:00:37
Colocar producto terminado en exhibidor	0:03:21	0:03:37	0:03:34	0:02:45	0:03:27	0:03:33	0:02:32	0:02:57	0:03:07
Movimiento	0:03:35	00:02:48	00:02:41	0:03:57	00:04:21	00:04:12	0:02:34	00:03:31	00:02:28
Transporte	00:04:57	00:05:47	00:05:39	00:05:21	00:06:11	00:05:31	00:05:10	00:06:11	00:04:58
Total	01:27:02	01:27:59	01:27:26	01:34:00	01:34:44	01:34:38	01:37:48	01:41:55	01:36:12
PROMEDIO	01:27:29			01:34:27			01:38:38		

Table 2. Observations for pastry dough

	Tiempo 1	Tiempo 2	Tiempo 3
Pesar Ingredientes de Cremado	0:01:52	0:01:44	0:01:55
Realizar cremado	0:11:59	0:11:24	0:11:45
Romper huevos	0:02:39	0:02:38	0:02:39
Pesar Leche	0:00:43	0:00:42	0:00:43
Pesar Ingredientes secos	0:01:11	0:01:49	0:01:28
Alistar Moldes	0:05:55	0:04:48	0:05:36
Engrasar Moldes	0:02:05	0:01:50	0:01:59
Limpiar mesa pastelera	0:00:07	0:01:08	0:00:35
Agregar Ingredientes al Cremado	0:04:30	0:04:22	0:04:28
Batir a velocidad máxima la mezcla	0:00:45	0:00:36	0:00:41
Agregar mezcla a moldes	0:11:15	0:12:06	0:11:35
Trasladar moldes a bandejero	0:00:29	0:00:27	0:00:29
Trasladar a horno	0:00:47	0:00:46	0:00:47
Hornear Pasteles	0:55:00	0:55:00	0:55:00
Total	1:39:16	1:39:20	1:39:40
PROMEDIO	1:39:25		

Lastly, we collected the information to elaborate technical sheets, this are important in a bakery because they provide detailed information on the ingredients and methods used in the production of each product. This information is critical for ensuring consistency in the quality of the products, as well as for food safety purposes. Technical sheets can help bakers to control the quality of their products, by ensuring that the same recipe and methods are followed each time a product is made (ASALDE, 2017).

The raw material used in the elaboration of different types of bread is flour, while the inputs used vary according to the dough to be prepared, as mentioned in the technical sheets of the elaborated doughs (Tables 3-8). By recollecting this data, we were able to see how much raw material is used in each the preparation of dough and how much final product it's made, we can make a comparison in the weight of the amount of raw material versus the weight of the final dough, we can observe this comparison on table 9.

Table 3. Technical Sheet for bun (bollo) dough

Masa de Bollo		
Presentaciones	Composición (kg)	
Pan de miga Gusano Manitos	Harina	10
	Harina de maíz	0
	Mantequilla	0.5
	Margarina	0.5
	Manteca	1
	Azucar	1
	Huevos	1
	Sal	0.2
	Levadura	0.2
	Esencias	0.1
	Agua	4.5
	Peso:	19

Table 4. Technical Sheet for rye (centeno) dough

Masa de centeno		
Presentaciones	Composición (kg)	
Pan Integral	Harina	2.5
	Harina de maíz	2.5
	Mantequilla	0.25
	Margarina	0.25
	Manteca	0.5
	Azucar	0.5
	Huevos	0.5
	Sal	0.1
	Levadura	0.1
	Esencias	0
	Agua	2.25
	Peso:	9.45

Table 5. Technical Sheet for sweet (dulce) dough

Masa de Dulce		
Presentaciones	Composición (kg)	
Ingerto Pan de chocolate Pan de piña Pan de frutas	Harina	5
	Harina de maíz	0
	Mantequilla	0.25
	Margarina	0.25
	Manteca	0.5
	Azucar	1
	Huevos	0.5
	Sal	0
	Levadura	0.1
	Esencias	0.05
	Agua	2
	Peso:	9.65

Table 6. Technical Sheet for puff pastry (hojaldre) dough

Masa Especial		
Presentaciones	Composición (kg)	
ambato empanada de queso empanada queso y cebolla	Harina	4.5
	Harina de maíz	0.5
	Mantequilla	0.25
	Margarina	0.5
	Manteca	0.5
	Azucar	0.5
	Huevos	0.5
	Sal	0.1
	Levadura	0.1
	Esencias	0.05
	Agua	1.75
	Peso:	9.25

Table 7. Technical Sheet for puff special (especial) dough

Masa Especial		
Presentaciones	Composición (kg)	
ambato empanada de queso empanada queso y cebolla	Harina	4.5
	Harina de maíz	0.5
	Mantequilla	0.25
	Margarina	0.5
	Manteca	0.5
	Azucar	0.5
	Huevos	0.5
	Sal	0.1
	Levadura	0.1
	Esencias	0.05
	Agua	1.75
	Peso:	9.25

Table 8. Technical Sheet pastry dough

Masa de pasteles		
Presentaciones	Composición (Kg)	
Vainilla Naranja	Margarina	2.4
	Azucar	2.4
	Huevos	2.4
	Jugo	1.6
	Royal	0.08
	Maicena	0
	Harina	4
	Licor-Escemco	0
	Crema de lechce	0.2
	Remolacha	0.5
	Polvo de cacao	0.4
	Peso:	13.98

Table 9. Wight raw materials vs Weight dough

	Peso Ingreso de Prouducción (kg)	Peso masa Final (kg)
Dulce	9.65	5
Bollo	19	10
Hojaldre	9.75	5
Centeno	9.45	5
Especial	9.25	5
Pasteleria	13.98	5

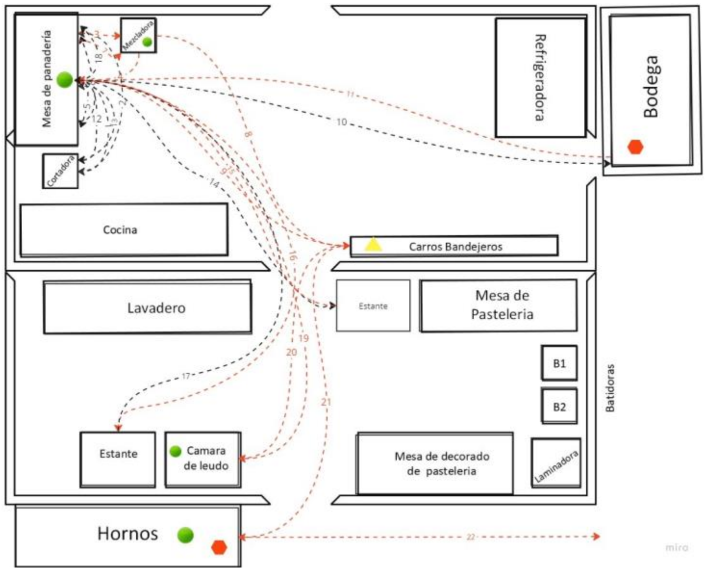
Analyze

Spaghetti Diagram

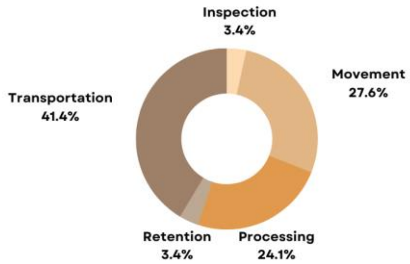
After the measure phase, the problems within both bakery and pastry processes were analyzed. It was decided to make a spaghetti diagram. According to Senderska et al. (2017), this is a useful tool that, by focusing on people as a factor affecting productivity, leads to the need to find options that allow optimizing workers' activities. Additionally, it allows us to have a clear identification of inefficient movements and areas, enabling changes to be made within work areas and their layout.

The first process to be analyzed is the preparation of sweet bread dough. Within the spaghetti diagram (as shown in Figure 5) it was observed that 29 activities were carried out, according to graph 1, 12 of them were used for the transportation of materials and utensils used in the process. On the other hand, 8 activities were part of the movements carried out by the baker, 7 were for the processing of the dough, one activity was focused on the inspection of the process, and also on retention. According to graph 2, it can be seen that, despite the fact that there is a greater number of activities dedicated to transportation and movement, processing activities are those that take up the most time within the process.

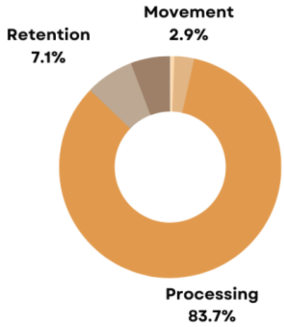
Figure 5. Spaghetti Diagram of the preparation of a sweet dough



Graph 1. Percentage of total activities covered by the bakery operator.

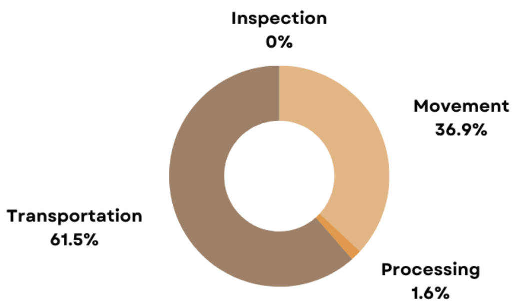


Graph 2. Percentage of the total time covered by the bakery operator.



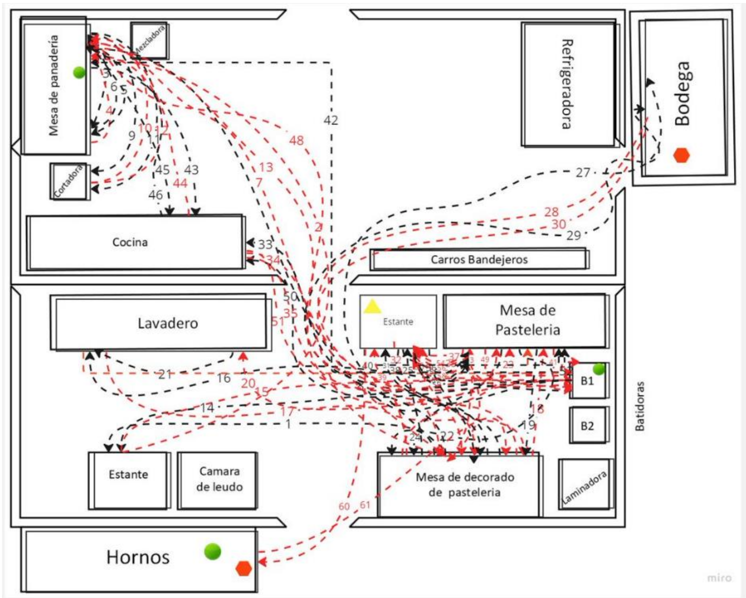
On the other hand, the baker covers a distance of 102 meters during this process in an area of 135 m^2. As shown in graph 3, 98.4% of the distances traveled are dedicated to the transportation and movement of materials and process utensils. Using formula recommended by Asalde (2017), the percentage of productive and unproductive activities was calculated. Regarding the percentage of productive activities, a percentage of 84% was obtained, and on unproductive activities a value of 16%. According to Betancourt (2017), good productivity is considered when there is a percentage between 70 and 75%, and therefore, a percentage of 25 to 30% of unproductive activities is acceptable. In comparison with these reference data, it is observed that the process is optimal in terms of productivity, however, improvements can be made.

Graph 3. Percentage of the total distance covered by the bakery operator.



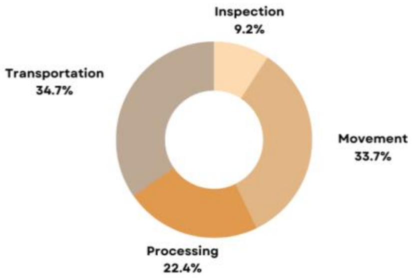
Now having an approach to the production process of a cake dough as seen in figure 6, the operator has many movements. Ninety-eight activities were identified, and a distance of 300 meters was covered. As shown in Graph 4, 34.7% of these activities were used for material transportation, 33.7% for movement, 22.4% for processing the batter, and 9.2% for inspection. Although transport and movement activities are performed most frequently, they occupy 16% and 9% of total production time, respectively, as shown in Graph 5.

Figure 6. Spaghetti Diagram of making a cake base dough

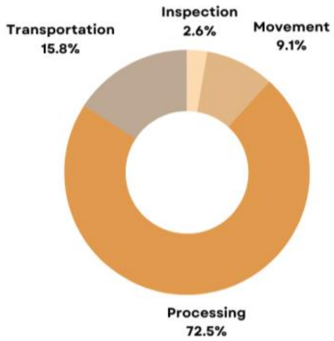


As shown in Graph 6, transport and movement activities occupy the highest percentage of distance, with a total of 92% of the operator's traveled distance is dedicated to these activities. Finally, referring to the percentage of productive activities, 75% was obtained, and for unproductive activities, 25%. These percentages fall within the recommended range by Betancourt (2017); however, significant improvements could be made, especially regarding the operator's traveled distance.

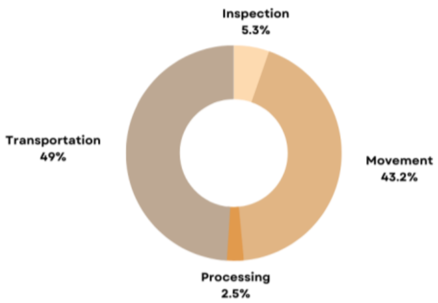
Graph 4. Percentage of total activities covered by the pastry operator.



Graph 5. Percentage of the total time covered by the pastry operator.



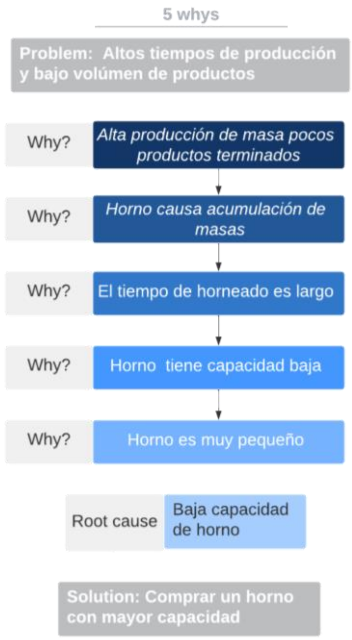
Graph 6. Percentage of the total distance covered by the pastry operator.



Bottleneck Identification

In order to identify the bottleneck of the processes, the Five Whys tool was applied. The main problem was the long production times and the low volume of production. The answer to the first why question was that there was a high dough production, but few finished products. The other four whys were answer, and lead to the main reason which was the low capacity that the oven had. This problem provoked that the trays with the semi-finished product to have to wait a long time for the oven to finish using it. An optimal solution to this issue is to buy a new oven with a higher capacity.

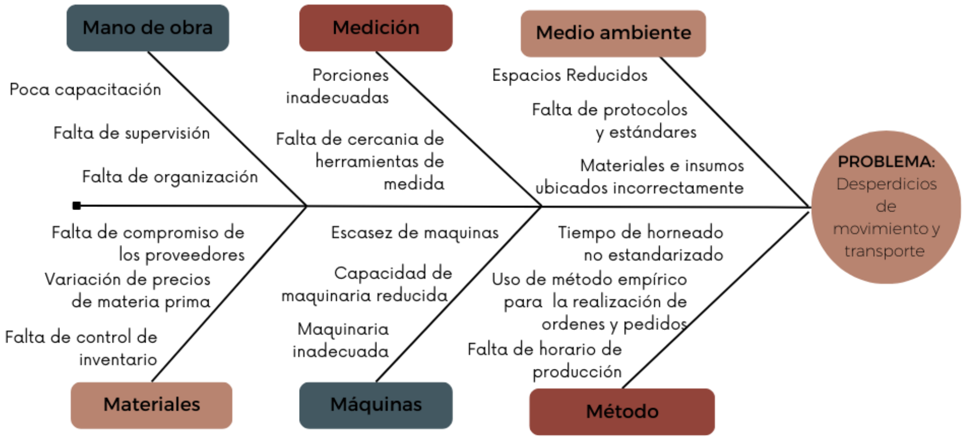
Figure 7. Five Whys



Ishikawa Diagram

As mentioned before the main problem in Duque Bakery was the waste of movements and transportation, through the Ishikawa diagram (Figure 8), we were able to identify several factors that were causing this problem. It also helped us to have a close contact with the employees since they themselves helped us find the reasons. Some of the main reasons were the lack of work protocols and standards, poor organization of materials, and lack of proximity to measurement tools.

Figure 8. Ishikawa Diagram



Improve

Department Planning

According to Tompkins et al. (2010), when it comes to defining the departments in a new facility, it is important to observe the production process and the requirements at each step. Following what was stated by Tompkins, the new departments for the new facility were established considering the activities for both processes, bakery, and pastry, and also the requirements of the owners. The total number of departments selected was 10, and Table 10 shows the name of each department. It is important to note that the current facility is of 135 square meters were as the layout proposals are going to be design for a facility of 200 square meters. This is because the owners of Duque Bakery are expanding their current production facility.

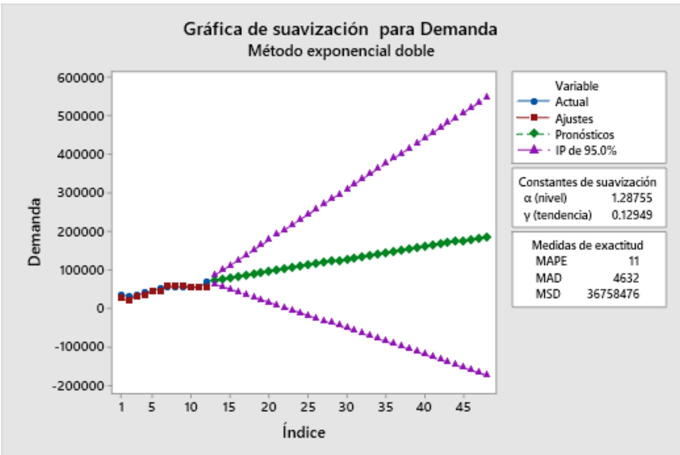
Table 10. Departments list

A1	Recepción
A2	Almacenamiento de materia prima
A3	Cuarto frio
A4	Lavado
A5	Formación de pan
A6	Pastelería
A7	Decorado de pasteles
A8	Cocina Industrial
A9	Horneado
A10	Maduración

Forecast

To make layout proposals, it is necessary to determine the bakery's expected demand to assess whether the proposed layout can meet it. Singh (2017) suggests that using forecasts can improve plant design, reduce costs, increase efficiency, and improve customer satisfaction. While the recommended period for a forecast is 5 years, Nahmias notes that this time frame can be adjusted based on the industry (2014). Due to the high demand in the bakery industry, the forecast was made for three years. The historical sales data shows a trend series pattern, which is why the double exponential smoothing method was used for the forecast. However, two outlier data points were removed due to assignable causes (start of bakery and national strike). The forecast's MAPE was 11%, which Ghiani considers a good forecast, allowing us to move forward with our planning (2005). Figure 9 shows the forecast made.

Figure 9. Forecast



Department Areas

The area of each department is calculated based on the number of machines needed within that department and their dimensions. At the same time, an allowence is established, which is the space that operators need to work. According to Martínez (2018), it is recommended to use an allowance of 0.5 m^2 per operator. On the other hand, the formula recommended by Imanullah et al. (2021) to calculate each of the areas, where n represents the number of machines needed is noted down below. And the results of using this formula are on Table 11.

$$Total\ Production\ Facility\ Area = (machine\ area\ \times n) + allowence$$

Table 11. Departments Areas

Departamentos		Objetos	n	Largo	Ancho	Alto	Machine Area(m2)	Total Production Facility Area (m2)
A1	Recepción	Escaleras	1	1.00	1.20		1.20	5
		Mesa de recepcion	1	0.70	1.50	0.75	3.76	
A2	Almacenamiento de materia prima	Gondola de supermercado	2	0.40	1.20	1.75	4.99	23
		Pallets	5	1.20	1.00	0.10	17.56	
A3	Cuarto frio	Estante	2	1.20	0.40	1.80	7.49	7
A4	Lavado	Lavabo	1	0.60	1.90	0.90	5.08	5
A5	Formación de pan	Mesa de panaderia	1	1.10	2.25	0.90	6.55	17
		Laminadora	1	0.50	0.70	1.27	2.31	
		Amasadora de espiral 20 lt	1	0.65	0.39	0.85	2.09	
		Cortadora de pan	1	0.60	0.52	1.30	2.21	
		Carro bandejero	2	0.69	0.55	1.70	4.24	
A6	Pasteleria	Mesa de pasteleria	1	1.10	2.25	0.90	6.55	14
		Batidora	1	1.22	0.73	1.56	3.42	
		Carro bandejero	2	0.69	0.55	1.70	4.24	
A7	Decorado de pasteles	mesa de decorado	1	0.70	1.85	0.90	4.77	11
		Mesa pequeña	1	1.10	0.50	0.90	3.81	
		Carro bandejero	1	0.69	0.55	1.70	2.37	
A8	Cocina Industrial	Cocina	1	1.90	1.50	0.90	6.46	6
A9	Horneado	Horno 18 latas	1	1.64	1.18	2.20	5.11	12
		Horno pequeño	1	0.60	0.95	1.67	2.80	
		Horno 10 latas	1	1.46	1.03	2.08	4.43	
A10	Maduración	Cámara de leudo	1	0.77	0.67	1.36	2.66	3
								104

Relationship between departments

Qualitative flow

The process for developing the qualitative flow relationship diagram is mentioned by Tompkins et al. (2010), and using the values developed by Muther. This should be constructed with the following steps: 1. Create a list of departments, 2. Conduct interviews with the people who perform activities in each department, 3. Define criteria for assigning proximity relationships and record the criteria as reasons for the relationship values, and 4. Establish the corresponding value for each pair of departments (Tompkins et al., 2010). Table 12 shows the relationships of the qualitative flow.

Table 12. Qualitative Flow chart

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	-	A	A	O	O	O	U	U	X	X
A2	-	-	X	U	E	E	E	U	U	U
A3	-	-	-	U	E	O	U	U	X	X
A4	-	-	-	-	I	E	E	U	U	U
A5	-	-	-	-	-	O	O	O	A	A
A6	-	-	-	-	-	-	A	O	A	U
A7	-	-	-	-	-	-	-	U	O	X
A8	-	-	-	-	-	-	-	-	E	U
A9	-	-	-	-	-	-	-	-	-	A
A10	-	-	-	-	-	-	-	-	-	-

Quantitative flow

The quantitative flow represents the flow of elements between departments in a period of time. These can be materials, information, or people. The process followed to develop this graph was explained by (Tompkins et al., 2010) and is as follows: 1. Create a matrix listing the departments in the first row and column of a table, 2. Establish a flow measure for the facility that accurately indicates the equivalent flow volumes. In this case, the unit of measure, bread units, was chosen. Record flow volumes on the graph, based on flow paths (Tompkins et al., 2010). Table 13 show the quantitative flow chart.

Table 13. Quantitative flow chart

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0	186113	0	0	0	0	0	0	0	0
A2	0	0	0	0	186084	186084	93042	0	0	0
A3	0	0	0	0	93042	93042	0	0	0	0
A4	0	0	0	0	18608	0	0	18608	0	0
A5	0	0	0	0	0	0	0	0	0	18608
A6	0	0	0	0	0	0	186084	0	0	0
A7	0	0	0	0	0	0	0	0	0	0
A8	0	0	0	0	0	0	93042	0	0	0
A9	0	0	0	0	0	0	0	0	0	186084
A10	0	0	0	0	0	0	0	0	0	0

Food Safety

For the optimal design of a food production plant, it is necessary to take into account the various factors involved in food safety. According to the Government of the Principality of Asturias (2019) there are several dangers and considerations that must be analyzed. The first refers to the physical dangers, such as the remains of metals, insects that can be found inside the raw materials. Analyzing this, it was considered to add pallets to locate the raw materials that used to be located on the floor, such as flour and sugar. The second one refers to the contamination of cleaning products. A viable way to avoid this, is by scheduling specific hours for cleaning and locating the dish washer area far away from the production's areas. Finally, the last one discusses the biological dangers such as cross contamination, salmonella, and staph. A reasonable method to evade this problem is by storing the raw material properly; also, consider the proper temperature at which the food should be stored and what foods cannot be together.

Layout Planning

The plant layout should be process-oriented, grouping personnel and equipment that perform similar functions together in the same area, also known as functional layout. Raw materials move based on the established sequence of operations, as the variety of products manufactured will result in different sequences of operations and material flows between workshops (ASALDE, 2017). Design layout is crucial in minimizing resource waste, and the BLOCPLAN algorithm is a useful tool to create a more efficient design in terms of the total distance traveled (Imanullah et al., 2021). Additionally, Hanggara notes that layout planning allows companies to be flexible in performing work activities, saving time and achieving economic use of space. SLP has several sections that offer multiple options to choose from to select the best one (2020).

BLOCPLAN

BLOCPLAN is an algorithm with a construction or improvement approach. uses a relationship chart as well as a from-to chart as input data for the "flow." Layout "cost" can be measured either by the distance-based objective or the adjacency-based objective (Tompkins et al., 2010). BLOCPLAN first assigns each department to one of the two (or three) bands.

Given all the departments assigned to a particular band, BLOCPLAN computes the appropriate band width by dividing the total area of the departments in that band by the building length. The complete layout is formed by computing the appropriate width for each band as described above and arranging the departments in each band according to a particular sequence.

To carry out the layout proposal, the DOSBOX software was used, to which, entering the data of relations and flow between departments, as well as the area of each department, returned a total of 20 layouts, of which 3 were chosen (figures 10-12) being layout number 14 (figure 13) the best for the score reached. Within the Siregar case study we can find the use of this software and how the BLOCPLAN results showed that the reduction of moment displacement improves(2020).

Figure 10. BLOCPLAN Layout 7

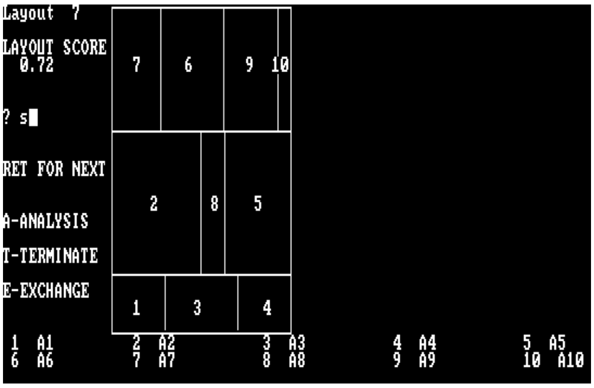


Figure 11. BLOCPLAN layout 11

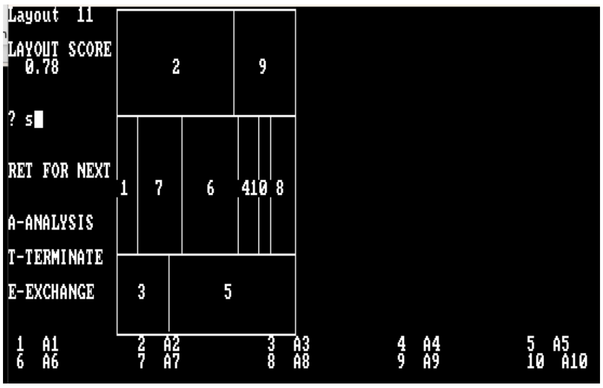
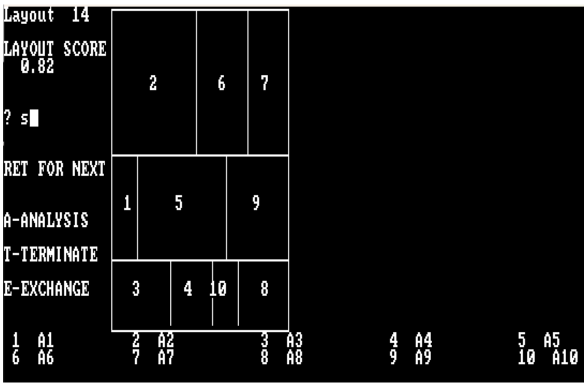


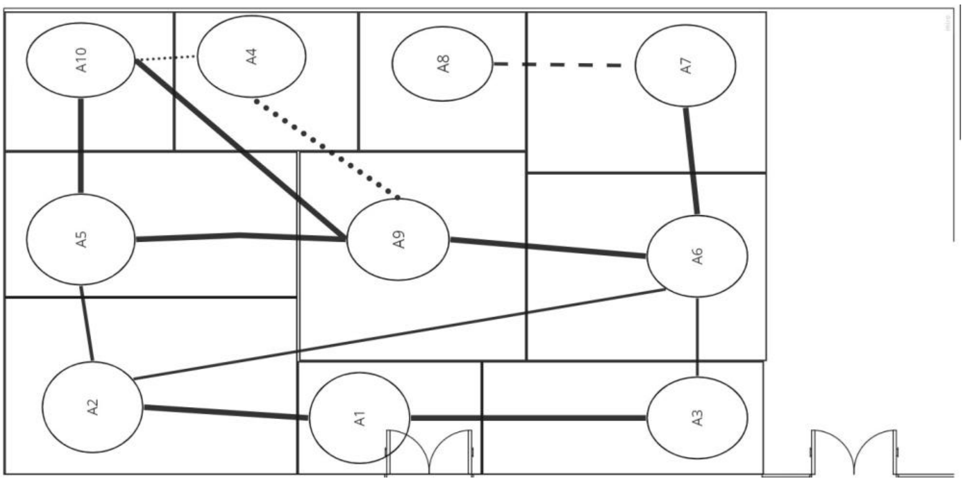
Figure 12. BLOCPLAN layout 14



SLP

Sistematic layout planning is qualitative method, based on the input data and an understanding of the roles and relationships between activities, a material flow analysis (from-to chart) and an activity relationship analysis (activity relationship chart) are performed. From the analyses performed, a relationship diagram is developed. Nexts, use the relationship diagram together with the space requirements to create a space relationship diagram. Finally, the space relationship diagram is used to generate layout alternatives in the form of a block layout (Tompkins et al., 2010). Figure 13 shows the proposed layout using the SLP approach.

Figure 13. SLP layout



LOGIC

Our final model is the LOGIC approach, this method is normally used for installations where the base structure is rectangular and describes a method that iteratively cuts the plane into horizontal and vertical lines (Tompkins et al., 2010). To develop this method, you start with the from-to table, where your flow is the material that passes from one department to another. Finally, a clipping tree is created as shown in figure 14, where all the grouped departments are initially found, and cut by grouping them into departments that have a strong relationship. This is repeated until each department is set individually. Once this tree cut diagram is built, the same cuts will be made in the final design, this groups and prioritizes the flow between departments. Figure 15 shows the result of the proposed layout using the LOGIC method.

Figure 14. LOGIC clipping tree

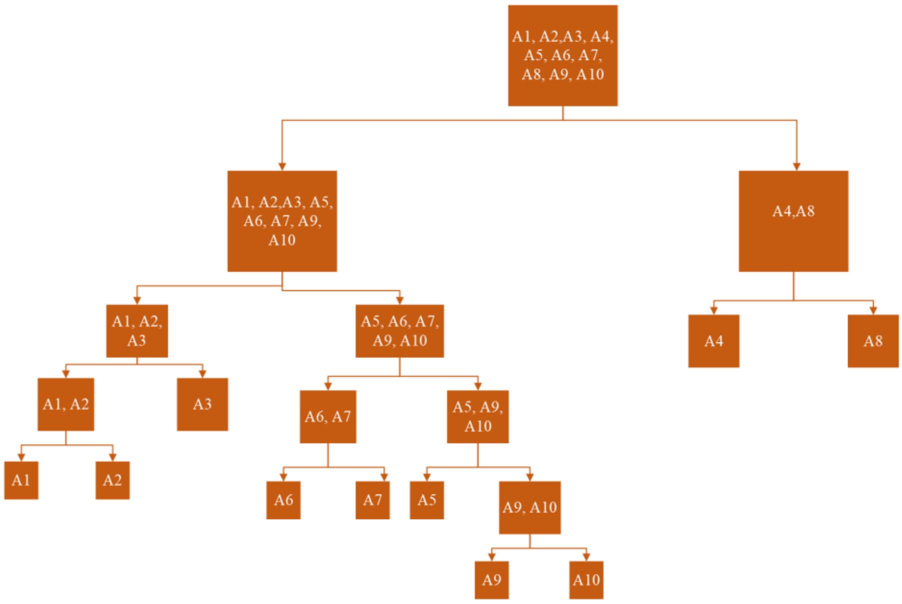
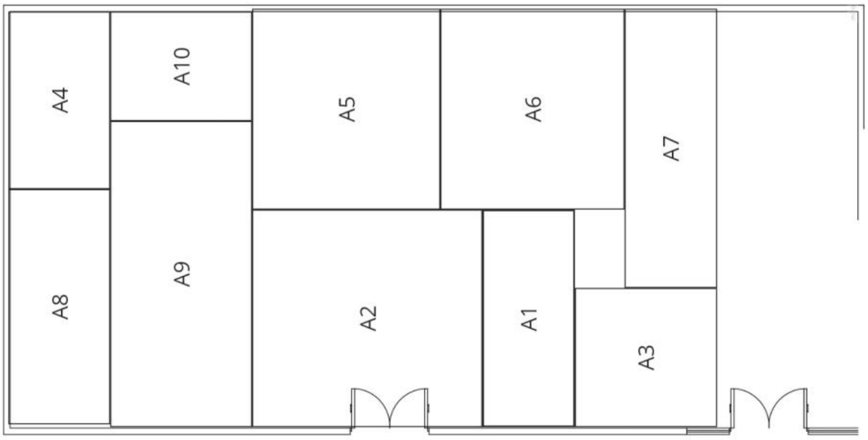


Figure 15. LOGIC layout



Adjacency Score

The adjacency score is useful to compare one or more alternative designs, since it maximizes the immediate flow between departments (Tompkins et al., 2010). This score is computed as the sum of all the flow values (or relationship values) between those departments that are adjacent in the layout. Letting xij = 1 if departments i and j are adjacent (that is, if they share a border) in the layout, and 0 otherwise, the objective is to maximize the adjacency score; the formula is the one show below:

$$\max z = \sum_{i=1}^{10} \sum_{j=1}^{10} f_{ij}\, x_{ij}$$

The adjacency between each pair of departments was analyzed for each alternative design, this was noted in the matrices shown in the tables 14, 15 and 16. The result of the objective function was a score of 1079316 for the BLOCPLAN alternative, 800190 for SLP method and finally 1060708 for the LOGIC approach.

Table 14. Adjacency matrix BLOCPLAN

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0	1	1	0	1	0	0	0	0	0
A2	1	0	0	0	1	1	0	0	0	0
A3	1	0	0	1	1	0	0	0	0	0
A4	0	0	1	0	1	0	0	1	0	1
A5	1	0	1	1	1	1	0	0	1	1
A6	0	1	0	0	0	0	1	0	1	0
A7	0	0	0	0	0	1	0	0	1	0
A8	0	0	0	0	0	0	0	0	1	1
A9	0	0	0	0	1	1	1	1	0	1
A10	0	0	0	1	1	0	0	1	1	0

Table 15. Adjacency matrix SLP

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0	1	1	0	0	0	0	0	1	0
A2	1	0	0	0	1	0	0	0	1	0
A3	1	0	0	0	0	1	0	0	1	0
A4	0	0	0	0	1	0	0	1	1	1
A5	0	0	1	1	0	0	0	0	1	1
A6	0	1	0	0	0	0	1	0	1	0
A7	0	0	0	0	0	1	0	1	1	0
A8	0	0	0	1	0	0	1	0	1	0
A9	0	0	1	1	1	1	0	1	0	0
A10	0	0	0	1	1	0	0	0	0	0

Table 16. Adjacency matrix LOGIC

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0	1	1	0	0	1	1	0	0	0
A2	1	0	0	0	1	1	0	0	1	0
A3	1	0	0	0	0	1	1	0	0	0
A4	0	0	0	0	0	0	0	1	1	1
A5	0	1	0	0	0	1	0	0	1	1
A6	1	1	1	0	1	0	1	0	0	0
A7	1	0	1	0	0	1	0	0	0	0
A8	0	0	0	1	0	0	0	0	1	0
A9	0	1	0	1	1	0	0	1	0	1
A10	0	0	0	1	1	0	0	0	1	0

Simulation

According to Cuba & Morales (2019), carrying out a simulation allows a study of the behavior of the real productive system. At the same time, it allows knowing the future behavior of a productive system while saving financial resources and time. It is for these reasons that it was decided to use simulation as a resource to evaluate the efficiency of the proposed layouts.

To carry out the simulation, some assumptions were considered. The first assumption is that the simulation was run for a month, since within a small company this period of time has a sufficient amount of data to carry out a significant statistical analysis (Cuba & Morales, 2019). At the same time, it allows obtaining valuable information on efficiency and the distance that operators must travel. Another assumption is that a bread dough and a final loaf represent 8 trays with 15 loaves on each of them and a cake dough and a final cake represent 4 trays with 6 cakes on each of them. This is due to the data that was collected during the timing of the process, which was used in the simulation. Finally, the operators worked a schedule from 8 a.m. to 4 p.m. for six days a week.

Through the use of *Flexsim* software, it allows to have a better understanding of the current process and a vision of the changes that can be made within the company. In this case. In this case, three simulations were carried out due to the three proposed layout designs (Blocplan, SLP and Logic), where each simulation maintained the same material and instruments, but the location of the departments was different.

In each simulation the total travel distance covered by the operators and the total throughput was analyzed. This was made in order to search for the minimum travel distance of the operators which can minimized the waste of movements and transportation. The results of the *Flexsim* dashboards can be seen in Figures 16,18,20. The distances where sum and transform into kilometers for the three layouts. The results obtained from the total distance traveled by the operators during the simulation for each of the proposed layouts can be seen in table 17. The difference between the throughput of the three layouts is minimum as can be seen in Figures 17,19,21.

Figure 16. Distance traveled by the operator in the Simulation Blocplan

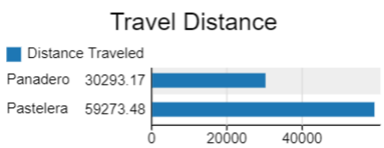


Figure 17. Throughput of breaths and cakes produced in the Simulation Blocplan

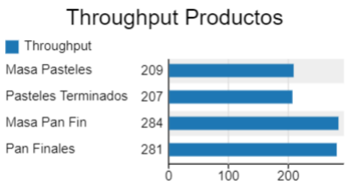


Figure 18. Distance traveled by the operator in the Simulation Logic

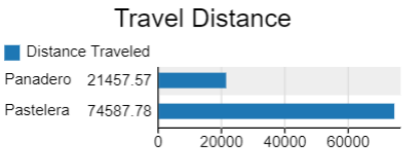


Figure 19. Throughput of breaths and cakes produced in the Simulation Logic

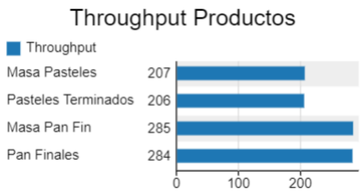


Figure 20. Distance traveled by the operator in the Simulation SLP

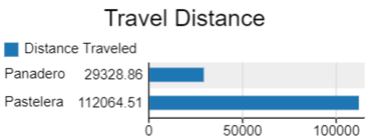


Figure 21.

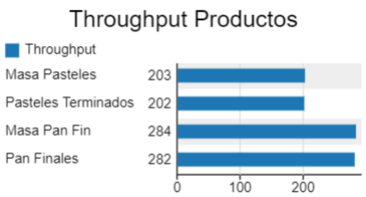


Table 17. Distance in km of the three proposed layouts

Model	Distance in km	Optimal
Blocplan	89.57	Yes
Logic	96.04	
SLP	141.40	

Economic Analysis

After developing the three layouts design it is important to analyze the economic impact that it will have on the company. In table 18 we can see all the costs that are necessary to develop the proposed layout. It is need an initial investment of $49.800, later as an annual fixed cost of $42,300.00 and an annual variable cost of $2,760.00. A break-even point of $84,600 was obtained, an ROI of 122%, which indicates that it is a profitable investment. In turn, a contribution margin of 50% and a profit margin of 80%.

Table 18. Initial Investment

Inversión Inicial

Dep.	Área	Objetos	Cantidad	Valor Unitario	Valor Total	Construcción de área
A1	Recepción	Escaleras	1	$ 2,278.02	$ 2,278.02	$ 5,500.00
		Mesa de recepcion	1	$ 425.00	$ 425.00	
A2	Almacenamiento de materia prima	Gondola de supermercado	2	$ 190.00	$ 380.00	$ -
		Pallets	3	$ 5.00	$ 15.00	$ -
A3	Cuarto frio	Estante	1	$ 290.00	$ 290.00	$ 3,315.00
A5	Formación de pan	Amasadora de espiral 20 lt	1	$ 1,100.00	$ 1,100.00	$ -
A6	Pastelería	Batidora	1	$ 27,500.00	$27,500.00	$ -
A9	Horneado	Horno 18 latas	1	$ 9,000.00	$ 9,000.00	$ -
					$40,988.02	$ 8,815.00
Inversión Inicial				**$**		**49,803.02**

Control

Within this last phase, several suggestions on food safety, organization of materials and possible improvements to be implemented within the bakery are presented. In order to have a more standardized work environment and work processes a checklist for preparations is recommended. The checklist refers to having a list with all the materials and instruments that are needed before starting to make the dough for bread or cakes. Also, the implementation of 5S´s for the workstations is necessary, for the purpose of having all the materials organized and not have to lose time on searching for them. On the other hand, a Bakery Safety Triptych is required. This tool is needed for have a clear procedure on how to handle materials to avoid breaches of food safety regulations. Finally for future predictions of sales, a daily production quantity record is suggested.

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

In conclusion, this study demonstrates a practical case in a small-sized Ecuadorian company where it was possible to minimize waste of movement and transportation and find viable solutions through the DMAIC methodology with a focus on layout improvement. We carried out an in-depth study of Duque's Bakery and proposed different tools that improved the volume of production, flow of materials, and decreased unnecessary movements and transportation.

Our main objective was to expand the production plant and improve the layout. We developed the layout proposals through different approaches that were evaluated in quantitative and qualitative terms. The layout chosen to be implemented was that of BLOCPLAN, as it was the best within the adjacency qualification and simulation results.

The redesign of the plant was carried out by modifying the position of some equipment to establish an optimal work environment for the operator, eliminating unnecessary movements in the process, and avoiding line crossings during journeys. The purchase of new equipment was proposed, allowing for greater production capacity.

After simulating the BLOCPLAN layout, taking into account the proposed new equipment, we observed that the production capacity for breads increased fourfold and for pastries threefold. Furthermore, according to the analysis conducted, the project is economically profitable.

Based on the findings of the study, there are several recommendations that we suggest for Duque's Bakery to improve its production efficiency and increase profitability. Firstly, the company should evaluate the possibility of increasing staff to handle the increased production demand. Secondly, it is essential to evaluate other production scenarios to identify more efficient processes and minimize unnecessary movements and transportation. Additionally, it is recommended to conduct a dedicated study on the number of ovens to resolve the bottleneck and increase the production capacity. Lastly, the company should also evaluate the possibility of franchise expansion to increase its market share and establish its brand in other locations. These recommendations will help Duque's Bakery to optimize its production processes, improve customer satisfaction, and achieve long-term growth and profitability.

The limitations of the study have impacted the data collection process and the ability to conduct a comprehensive analysis of the project's implementation. Firstly, due to staff cuts, more process data could not be collected, which may have limited the accuracy of the findings. Secondly, while historical data from 2021 and 2022 was available, current data from 2023 was not collected due to a database migration, which could have provided valuable insights into the current state of the process. Lastly, due to the construction's duration, complete implementation project tracking cannot be carried out, which may have limited the ability to measure the full impact of the project's implementation. Despite these limitations, the study was able to identify several opportunities for process improvement and provide valuable recommendations for Duque's Bakery to optimize its production processes and improve profitability.

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