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Productivity Improvement and Operational Efficiency in Office Furniture Manufacturing: A Work Study Case in Northeastern México

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Abstract

The main objective of this research is to increase productivity and operational efficiency in a medium-sized company in northeastern Mexico dedicated to the design, manufacture, and distribution of office furniture. The drawer assembly process was identified as a critical point due to its direct impact on production capacity. The methodology employed was based on an empirical-analytical approach, combining direct observation on the plant floor with classic industrial engineering tools. On-site visits were conducted to document the process flow and validate the information with operational staff. The analysis included operation, flow, and route diagrams, 5W + 2H, the 5 Whys technique, the 9's methodology, time and motion studies, as well as the application of the MOST (Maynard Operation Sequence Technique). Three key areas of opportunity were identified: work area design, imbalance in work-in-process inventory, and lack of a suitable clamping device for assembly. The proposals focused on redesigning the work area to optimize material flow and allow two operators to work simultaneously. The inventory balancing strategy reduced overproduction and inefficient use of space. The design of an ergonomic clamping device allowed for standardization of the process, increased safety, and improved operational precision. The results estimate a 34.75% reduction in assembly time per drawer, decreasing from 80 to 52.2 seconds based on MOST-derived predetermined time analysis, which projects an increase in production capacity from 315 to 483 drawers/day under single-shift continuous production. The improvement proposals demonstrated high technical feasibility for improving productivity in SMEs. Post-implementation measurement is recommended to validate these projections.

Keywords
Assembly, Improvement, Productivity, Operational Efficiency, Work Study.

1. Introduction
The optimization of productive processes and services requires various methodological tools that allow for the systematic and strategic representation, analysis, and quantification of operations and operational activities (Freivalds and Niebel, 2013; Groover, 2007). This paper presents the analysis conducted in a company located in northeastern Mexico that manufactures office furniture in the city of Monterrey, with an emphasis on design, functionality, and quality of products and services. The objective of this work is to increase the productivity and operational efficiency of the company through observation and analysis of current production methods and systems, identifying critical operations and bottlenecks, as well as eliminating unnecessary movements and waste throughout the process. The importance of this research lies in proposing feasible and replicable improvements based on industrial engineering

techniques such as methods engineering, time and motion studies, as well as work design to optimize productivity and efficiency in the company, specifically regarding manufacturing, inventory, and processes.

Currently, the company operates on a made-to-order basis, offering more than 59 types of office products, including filing cabinets, tables, chairs, lockers, bookshelves, among other products, functioning as a batch production system with high variability, making process automation unfeasible. For this study, the filing cabinet (drawer) manufacturing process was selected due to its high demand and previous work in optimizing material cuts. The raw materials used include melamine sheets of 6 and 12 mm, PVC material for the veneering process, nails, wood adhesives, hardware, and protective films. The main clients are companies and institutions with storage and document organization needs. The estimated demand for filing cabinets is approximately 600 units per year. This paper presents a case study of application and results that demonstrate reductions in unproductive times, lower operational variability, and engineering proposals based on a waste analysis and standard time measurement. Limitations and considerations for the implementation and integration of these tools into the company's management systems are discussed.

2. Literature Review

Continuous improvement of productive processes and services is based on the use of various tools that allow for the systematic and clear description, analysis, and measurement of operational activities. In work study, methods engineering techniques such as operation diagrams, flowcharts, and route diagrams are used to facilitate visualization and understanding of process sequences, establish the flow of materials and physical movements, and also facilitate opportunities for simplification and improvement (Frievalds and Niebel, 2013). Likewise, the application of measurement and standards from time studies and work design is a widely used foundation for a company or business to increase its productivity through the analysis and improvement of workstations and the establishment of precise time standards. Groover (2007) comprehensively addresses work systems, design, and measurement to understand the impact of improvement proposals that can be generated from an accurate analysis and diagnosis in a project. To analyze the causes of inefficiencies, techniques such as the 5 Whys are employed, which allow for reaching the root of the problem through successive questioning (Ohno, 2019), while the 9S methodology offers a practical framework to improve order, cleanliness, and standardization of workstations in order to foster a commitment to creating a safer and more productive work environment (Imai, 1986). It is worth noting that 9S extends the well-known 5S framework (Sort, Set in order, Shine, Standardize, Sustain) by incorporating four additional principles: Safety, Spirit, Ethics, and Environment. These extra dimensions explicitly address worker well-being, organizational culture, ethical conduct, and environmental responsibility, making 9S particularly well-suited for SME contexts where workforce engagement and sustainability are critical success factors.

More recently, Aldavert et al. (2023) provide detailed methodologies for implementing the principles of 5S that help mitigate clutter and lack of signage in assembly and inventory areas. Regarding inventory management, authors like Chopra (2019) and Stevenson (2017) provide theoretical frameworks and tools for efficient inventory management, highlighting the importance of balancing demand and supply and optimizing stock levels in inventories, yielding benefits such as space release and reduction of costs associated with storing excess parts. Another key part of project analysis focuses on identifying and eliminating waste, a fundamental concept of Lean Manufacturing developed by Womack and Jones (2013), which defines principles for identifying and eliminating “Muda” (waste) in processes to create value. Liker's (2004) work delves into the philosophy behind Lean, emphasizing the importance of standardization and continuous improvement for operational efficiency. Complementarily, time and motion studies provide empirical evidence regarding the duration and efficiency of activities, offering essential quantitative inputs for continuous improvement (Barnes, 1991). In this context, the application of the MOST (Maynard Operation Sequence Technique) allows for breaking down operations into basic elements and quantifying them in predetermined times, facilitating the acquisition of reproducible standard times and comparison between work design alternatives (Maynard, 1992).

Recent research has shown that time and motion study techniques remain relevant (Nicole, Vivian and De Oliveira, 2022). On the other hand, Ovalles-Castiblanco and Cárdenas-Aguirre (2016) state in their research that one of the most commonly used techniques today is direct observation and stopwatch time studies. Through detailed analyses of standard times and the reorganization of various activities, it is possible to create a continuous production flow, optimizing resources and improving the system’s overall performance (Zaman and Hosseinabad, 2021). Recent studies present case studies with positive results that include the application of the aforementioned tools (Andrade et al., 2019; Sauceda López et al., 2021; Ortiz Porras et al., 2022). Bravo Fernández (2023) analyzes a recent case study using a combination of Lean Manufacturing tools, 5S, Andon, and Standard Time. Kamble et al. (2026) conducted a study on standardization and value stream mapping (VSM). Regarding MOST specifically, Hodson (2002) provides a comprehensive reference for its industrial application and validation, while Salvendy (2012) further establishes its reliability for predetermined time determination in manual assembly operations.

This work integrates a robust set of applications derived from classical and modern industrial engineering to diagnose, analyze, and propose solutions to operational problems with the aim of improving efficiency, productivity, and the work environment in the company. While previous studies have applied individual tools such as MOST, 5S, or layout redesign in isolation, a notable gap exists in the literature regarding their simultaneous integration combined with CAD-based fixture design within resource-constrained SMEs in developing economies. This study addresses that gap by presenting a holistic, low-cost improvement framework applicable and replicable in similar manufacturing contexts.

3. Methods

The research was designed under a mixed methodological approach that integrates quantitative and qualitative techniques for optimizing productive processes in a small and medium-sized enterprise (SME) dedicated to manufacturing office furniture. The methodology aimed to obtain a rigorous diagnosis of the current state of the filing cabinet (drawer) assembly process, identify areas of opportunity, and propose improvements based on empirical measurements and structured analysis. The methodological process was divided into four main phases: situational diagnosis, data collection and analysis, design of improvement proposals, and preliminary validation.

Phase 1. Situational Diagnosis and Information Gathering Activities began with field visits conducted on four different occasions to the company's production center, located in the northeastern region of Mexico. During the visits, an exhaustive information gathering was carried out through direct observation, interaction with operational staff, and semi-structured interviews with the owner and the process supervisor. The purpose of this phase was to thoroughly understand the workflow, current methods and conditions, as well as to physically document the environment and processes. For the initial analysis, the use of Operation Diagrams, Flow Diagrams, and Material and Personnel Route Diagrams was applied, aiming to map the sequence and movements within the assembly area and the interrelated areas. This diagram allowed for the identification of redundant movements and sub-optimal locations for both inventory and workstations. Simultaneously, the 5S techniques were implemented to assess and diagnose the organization, order, and cleanliness in the area, identifying unnecessary elements, lack of signage, and storage issues that affect operational efficiency. An analysis using the 5W+2H method was conducted to structure and delimit each area of opportunity, determining what, why, where, when, who, how, and how much regarding the identified issues, which reinforced the contextual and operational understanding of the process. Additionally, the 5 Whys technique was employed to analyze in depth the root causes related to the main problem identified: the delay in drawer production. This approach allowed for breaking down the problem into specific factors associated with the area design, inventory balancing, and deficiencies in fastening devices for assembly.

Phase 2. Measurement and Quantitative Analysis Based on the initial findings, the second phase included methodical measurement activities to quantify times and movements within the assembly process. The MOST (Maynard Operation Sequence Technique) was applied for the time study, as this tool allows for breaking down operations into basic movements and establishing time standards quickly and accurately. To do this, videos were recorded, and times were taken at various stages of assembly, from receiving the cut and veneered components to the manual assembly of the filing cabinets. During this phase, a detailed physical count of the inventory in process was conducted, identifying overproduction and imbalance in the pieces, particularly in backs for letter and legal-size filing cabinets. This inventory was categorized and quantified to evaluate its impact on space and workstation efficiency. The information was compared against estimated annual demand data (approximately 600 units) to establish appropriate levels and balancing strategies that avoid unnecessary accumulations and waste of space. Additionally, Flow Diagrams and route analyses for raw materials and products in process were developed, allowing for the visualization and quantification of materials and operator movements. This was key to identify bottlenecks, unnecessary movements, and non-value-added activities, which are fundamental for the recommendations.

Phase 3. Design of Improvement Proposals In this phase, the proposals were conceptualized based on the collected data and supported by principles of lean manufacturing, ergonomics, and time study. An optimized layout for the assembly station was designed, considering the logic of sequential flow of components and minimizes unnecessary movements and displacements. The design includes a space dedicated to the temporary reception of materials, a workspace with standardized arrangement of tools and parts, as well as an immediate warehouse for finished products.

This facilitates the application of the 5S principles and improves productivity by allowing operators to perform each task with orderly and controlled access to supplies. Simultaneously, the creation of a fastening device or fixture for drawer assembly was proposed. This fixture, modeled in CAD software in three dimensions and designed to be manufactured with existing reused materials in the workshop, aims to improve stability and precision in assembly, reduce errors, facilitate instruction for new operators, and decrease injury risks associated with manual handling and unstable use of tools like nail guns. Its design includes internal guides and standard measures to correctly position the pieces during assembly. A plan for inventory balancing was also proposed to maintain only the necessary quantities of parts for effective production, avoiding overproduction that obstructs flow and occupies unnecessary space. This balancing involves a communication and coordination system between cutting, veneering, and assembly areas to synchronize production with actual demand and optimize the use of space and resources.

Phase 4. Preliminary Validation and Impact Analysis Following the definition of proposals, a practical simulation of assembly was carried out using the fixture and the proposed new layout, through direct observation and timing using Basic MOST tables. The simulation consisted of performing a complete assembly sequence of one drawer unit with two operators at the redesigned workstation, using the physical prototype of the clamping device. Each motion sequence was decomposed into MOST subactivities (General Move, Controlled Move, and Tool Use sequences), assigned standard TMU values according to the Basic MOST tables, and summed to obtain the projected standard time. The simulation was repeated three times with different operators to verify consistency. This validation allowed for estimating a projected reduction in operation time, a key indicator of improvement in efficiency. It is important to note that all time and capacity figures reported in this study (34.75% reduction, 315→483 drawers/day) are projected estimates based on MOST-derived standard times from this simulation; they represent expected gains pending post-implementation measurement. Additionally, the improvement in inventory balancing was quantified, projecting an increase in the number of filing cabinets ready for assembly, optimizing the use of inventory in process. Finally, a theoretical evaluation of economic and technical feasibility was conducted, considering the typical limited financial capacity of an SME, the expected return on investment, and the impact on productivity and labor safety. The low cost associated with manufacturing the device with waste materials and the simplicity of implementing the new layout were highlighted, attributable to close collaboration with operational staff and the integration of methods engineering tools and work study. This comprehensive methodological approach, which combines qualitative diagnosis, quantitative measurement, computer-aided design, and empirical validation, ensures that the improvement proposals are practical, technically sound, and aligned with the real capabilities of the company, significantly increasing the likelihood of success in their implementation.

4. Results and Discussion

Data analysis was carried out using a combined methodology of direct observation, qualitative and quantitative information, and the application of industrial engineering tools to identify, diagnose, and quantify opportunity areas in the office furniture assembly process. Initially, visits and analyses were carried out in the workshop, observing the assembly of different products, the flow of materials, and the operations performed by the staff. Interviews were also conducted with operational staff and process supervisors. Table 1 shows the main production processes observed.

Table 1. Production process observed.

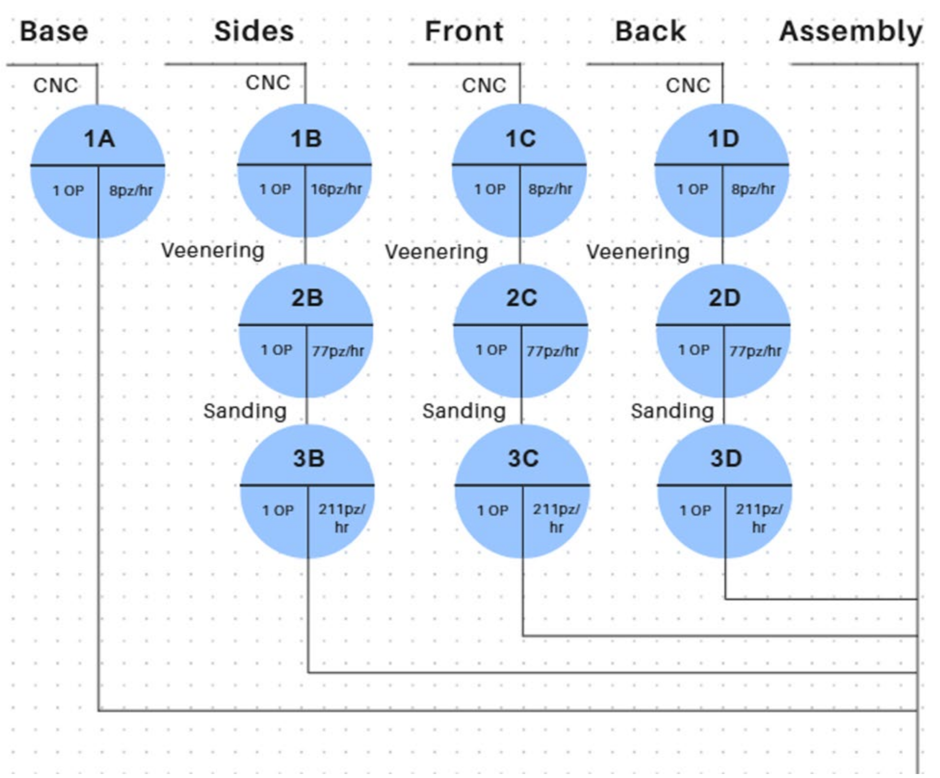
Production areas visited
Saw Cut
CNC lathe
PVC veneer operation
Assembly and finishing

Additionally, Table 2 shows a preliminary summary of the operating times for some of the main operations of the filing cabinets process that were observed during the first visits. Some of the activities consist of several steps, so as can be observed in the Table 2, some processes are broken down into parts.

Table 2. Main operating times of filing cabinets process

Product	Area	Activity Number	Number of parts	Total Time
Designed Book case	CNC.	Part 1 of 3	14	00:41:59
Designed Book case	CNC.	Part 2 of 3	12	00:25:57
Designed Book case	CNC lathe	Part 3 of 3	8	00:23:00
Cover and pedestal	CNC lathe	Part 1 of 4	3	00:27:15
Front and sides of drawers	CNC lathe	Part 2 of 4	15	00:34:20
Drawers' parts	CNC lathe	Part 3 of 4	7	00:29:58
Base, Back and front of drawers	CNC lathe	Part 4 of 4	17	00:25:52
Sides and front of a cabinet	CNC lathe	1	6	00:23:24
TV furniture.	Assembly	1	1	01:58:23
General cutting	Saw operation	1	1	00:11:23
Movil drawer for letter size	Veneer operation	4	32	00:29:44
Double drawer	Assembly	1	1	01:00:52
Drawer	Veneer operation	4	9	00:59:50
Screen	Veneer operation	6	4	01:24:29
Covers	Saw operation	1	-	00:14:54
Formica doors	Saw operation	4	-	00:17:37
Designed furniture	Veneer operation	8	-	00:16:55

Figure 1 shows the preliminary operations diagram created to understand the assembly of the components for the drawers. The filing cabinet consists of four components: base, sides, front, and back, which are assembled into a single unit.



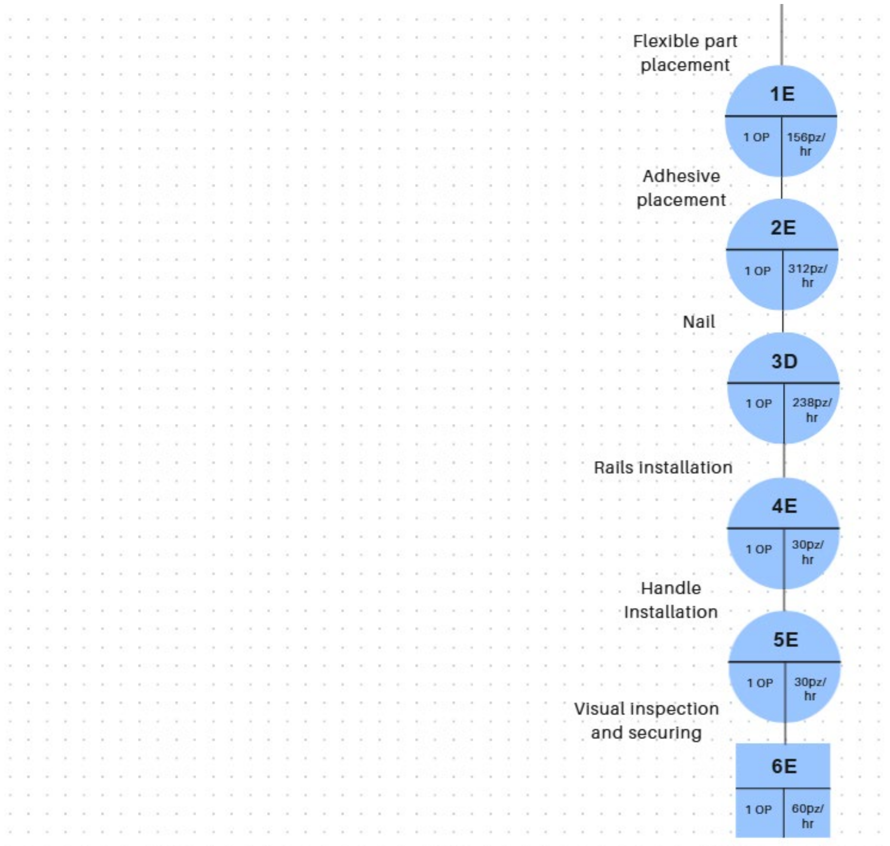


Figure 1. Preliminary operations diagram of the assembly process of filing cabinets.

Also, the process was analyzed using Flow Process Chart. Figure 2 shows part of the flowchart created for the work of one of the drawer models in the assembly area.

Flow Process Chart					
Diagrammed concept: FILING CABINET					
Diagram No. 1			Component: Assembly		
Diagram starts at: CNC			Diagram ends at: Review		
Prepared by: Team 2		Date:11/05/2025		Sheet:1	Of:5
No.	**Activity description**	**Symbol**	**Time (Pcs/hr)**	**Distance (meters)**	**Observations**
1	Placing pieces in Fixture	● ⇨ D ▽ □	156	0	Assembly processes are carried out with the help of a Fixture
2	Adhesive application	● ⇨ D ▽ □	312	0	Adhesive is applied
3	Nailing	● ⇨ D ▽ □	238	0	The assembly is secured with nails
4	Rail installation	● ⇨ D ▽ □	30	0	Rails are installed
5	Handle installation	● ⇨ D ▽ □	30	0	Handles are placed
6	Visual and fastening verification	○ ⇨ D ▽ ■	60	0	A quick inspection of the assembly quality is performed.

Figure 2. Excerpt of Flow process chart of filing cabinets.

Additionally, Route Diagram was used to understand the flow of components and analyze their importance in the process. Figure 3 shows the route diagram for the drawer assembly area,

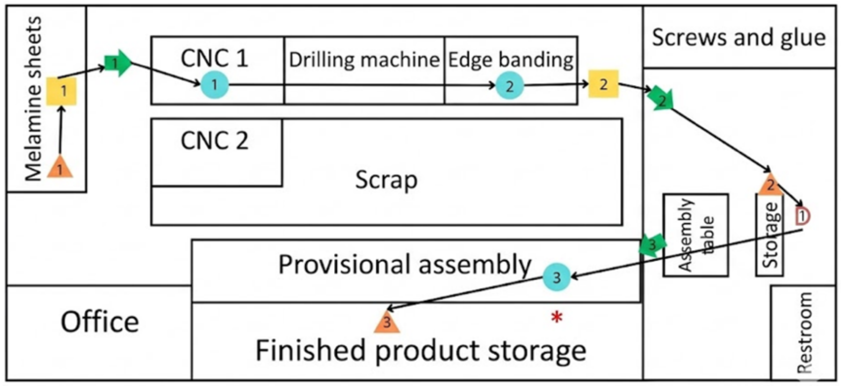


Figure 3. Diagram of the assembly area route.

On the other hand, 5W+2H and 5 Whys analysis tools were systematically applied to define and analyze identified areas of opportunity. Table 3 summarizes the 5W + 2H analysis.

Table 3. 5W+2H analysis.

5W + 2 H		
5W	What is the problem?	The assembly area is experiencing production delays and is unable to meet current demand requirements for drawer assembly.
	Why is it a problem?	The drawer assembly operation does not have work standards, and there is a lack of control over parts, tools, and procedures.
	Where do we encounter the problem?	Drawer assembly area
	Who is impacted?	The customer, upon not receiving their order on time, as well as the production area, upon not meeting the requirement.
	When did we first encounter the problem?	After the veneering operation
2H	How do we solve this problem?	A work design and layout proposal will be developed for the organization of the area.
	How much will it cost?	Expected gains pending post-implementation measurements.

The analysis of eight types of waste in Lean Manufacturing was also used to categorize the inefficiencies observed. Waste was identified, such as waiting due to not having a designated space for tools and materials. In addition, it was observed that excess inventory is generated due to surplus material or shortages of required parts that cannot be located, which leads to unproductive time. On the other hand, there is excess movement and overprocessing by operators due to poor design in the assembly area. Problems were also found in the flow of materials between workstations. Finally, a surplus of 200 parts was counted due to overproduction or defective parts, which are constantly reworked to meet demand and represent excess inventory.

On the other hand, a 9S implementation plan was carried out in the work area, obtaining positive results after implementation. Table 4 shows the before and after of the 9S implementation.

Table 4. 9S Application

9S	Before	After
Sort	Unnecessary parts placed in the floor	Remove unused parts from workplace
Set in order	Products pickup randomly	Products pickup in a systematic way
Shine	Workplaces are not clean	Neat and clean workplace
Standardize	No proper racks used	Used standard racks
Sustain	No sustain practices.	Audits are conducted periodically
Safety	Safety equipment not used properly	Used safety equipment
Spirit (Teamwork)	No work team in assembly area	Group work to sustain 9S
Simplicity	No working flow chart	Use of systematic production chart
Skill	No training program	Project a training program

Based on this analysis, three main areas of opportunity were identified: 1) Work area design, 2) Balancing inventory of work in progress, and 3) Improvements to the assembly clamping device.

To implement the proposed improvements, a detailed space analysis was performed, a time study was conducted using the MOST technique, and the existing inventory was counted. At the same time, current operating times were recorded, and the assembly of a drawer was simulated using the new work area design and the improved clamping device.

1) Regarding the design of the work area, the assembly process route from raw material to finished product was analyzed, considering the operator's movements and contemplating space for a temporary warehouse for components required for assembly. A transport cart and the necessary equipment to include a work table for product assembly were also considered. An area for the finished product was considered, taking into account the batch workflow and options for simultaneous work by two operators. This resulted in a substantial improvement in the order, cleanliness, and standardization of the process, as well as preparation for fluctuations in high demand by allowing simultaneous assembly by two operators. Figure 4 shows the two layout options mentioned above.

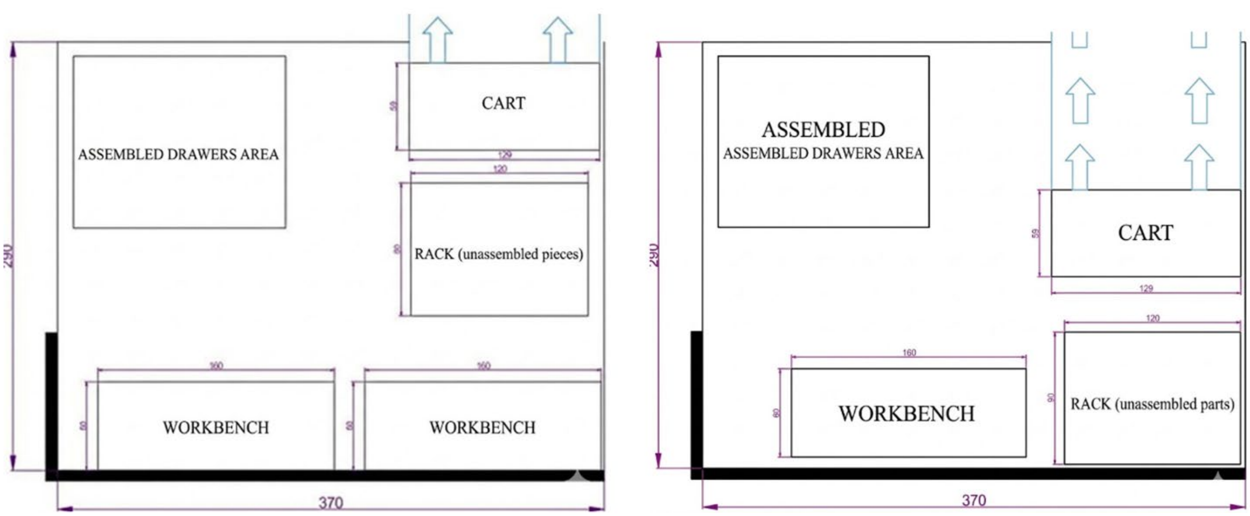


Figure 4. Proposed layout for the area design

2) Regarding excess inventory, an imbalance of 727 pieces was identified, of which only 52 assembled drawers could be obtained, with overproduction of letter-size filing cabinet backs (266 pieces) and legal-size filing cabinet backs (73 pieces). The proposal was to cut and groove the surplus pieces to transform them into missing components. 140 pieces were cut and 185 pieces were grooved, increasing the number of assembled drawers to 106 by sorting and reusing the existing material as excess inventory. Figure 5 shows one surplus inventory rack.

Figure 5. Surplus inventory rack.

3) Regarding the design of a new fastening device, this proposal is necessary because the current design had several problems. It gave the operator less control during assembly, which led to more errors and made it more difficult to train and instruct new operators. It was also less stable, putting workers at risk of injury when using the nail gun. The operators in charge of the assembly process were interviewed to better understand the process, the needs, the risks of defects, and the temporary losses during the process. Subsequently, a 3D model was designed in CAD software of a proposed clamping device that could be made with existing raw materials (melamine) in the workshop, without the need to purchase additional materials for the prototype. The design consists of a 3-sided cube with internal guides that ensure precise positioning of the parts. It is compatible with all stages of assembly, improves safety and accuracy, and aids in the training of new operators. Figure 6 shows the design of the device.

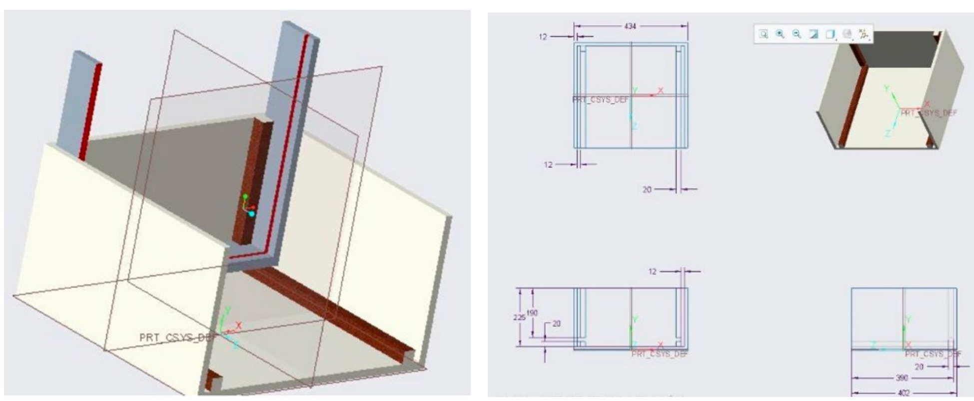


Figure 6. Design of Clamping device

To verify the usefulness of the proposals made, functional and dimensional validation tests were conducted on-site using a physical prototype with different operators at the workstation. The proposed clamping device consists of three melamine panels that serve as guides for assembling the drawers; it is a three-sided cube with dimensions extended to those required for a drawer. Inside, there are four wooden rails that serve as a guide for the operator to know exactly where to position the parts. Additionally, a gap was left between the horizontal and vertical rails so that they function properly at any stage of the assembly process. Operating times were recorded by simulating the assembly of a drawer with the new work area design, as well as the implementation of the designed clamping device. The Basic MOST technique was used for this purpose, considering the distances and elements of the proposal. Figure 7 shows part of the MOST analysis performed in this process.

Based on the analysis, the impact of the work area design proposals and the implementation of a clamping device with better adaptations according to the needs and characteristics of the sequence of operations was evaluated. Due to time constraints, a formal cost-benefit analysis for the implementation of this proposal has not yet been conducted;

therefore, it is recommended that it be carried out at a later stage, including the material and labor cost of the fixture, the holding cost savings from the 727-piece inventory reduction, and the projected financial impact of the capacity increase.

Sequence Models	PF	FR	SIMO TO	TMU
$A_6\ B_0\ G_1\ A_6\ B_0\ P_1\ A_0$	( )			140
$A_6\ B_0\ G_1\ A_6\ B_0\ P_1\ A_0$	( )			140
$A_1\ B_0\ G_1\ M_1\ X_0\ I_3\ A_0$	( )			60
$A_1\ B_0\ G_1\ (A_1\ B_0\ P_3)\ A_1\ B_0\ P_1\ A_0$	2			120
$A_0\ B_0\ G_0\ A_1\ B_0\ P_3\ A_0$	( )			40
$A_1\ B_0\ G_1\ M_0\ X_0\ I_6\ A_0$	( )			80
$A_1\ B_0\ G_1\ A_1\ B_0\ P_0\ A_0$	( )			30
$A_0\ B_0\ G_0\ M_0\ X_1\ I_1\ A_0$	( )	4		80
$A_1\ B_0\ G_0\ (M_0\ X_1\ I_1)\ A_0$	4			90
$A_0\ B_0\ G_0\ A_1\ B_0\ P_1\ A_0$	( )			20
$A_1\ B_0\ G_1\ M_1\ X_0\ I_0\ A_0$	( )			30
$A_0\ B_0\ G_0\ A_1\ B_0\ P_3\ A_0$	( )			40
$A_0\ B_0\ G_0\ M_1\ X_0\ I_3\ A_0$	( )			40
$A_1\ B_0\ G_1\ (A_1\ B_0\ P_3)\ A_1\ B_0\ P_1\ A_0$	2			120
$A_0\ B_0\ G_0\ A_1\ B_0\ P_3\ A_0$	( )			40
$A_1\ B_0\ G_1\ M_0\ X_0\ I_6\ A_0$	( )			80
$A_1\ B_0\ G_1\ A_1\ B_0\ P_0\ A_0$	( )			30
$A_0\ B_0\ G_0\ M_0\ X_1\ I_1\ A_0$	( )	4		80
$A_1\ B_0\ G_0\ M_0\ X_1\ I_1\ A_0$	4			90
$A_1\ B_0\ G_1\ M_1\ X_0\ I_0\ A_0$	( )			30
$A_0\ B_0\ G_0\ A_6\ B_0\ P_1\ A_0$	( )			70
TOTAL TIME	TMU´S		1450	
	SECONDS		52.2	

Figure 7. Excerpt from MOST analysis

As a result of the proposals, the MOST-based simulation projects a 34.75% reduction in assembly time per drawer, from 80 to 52.2 seconds. These are estimated values derived from predetermined time analysis (MOST TMUs) and should be interpreted as projected gains pending post-implementation validation through direct observation and stopwatch measurement. The projected increase in production capacity from 315 to 483 drawers/day assumes a single-shift operation (8 hours), two operators working simultaneously at the redesigned workstation, and continuous production without stoppages. Regarding the inventory imbalance of 727 pieces, the root cause was identified as a lack of synchronization between the cutting, veneering, and assembly stages, where upstream areas operated on independent production batches without coordination with actual downstream assembly demand. It is therefore recommended that the production planning system be adjusted to implement pull-based or demand-driven batch sizing between stages, preventing this type of WIP accumulation from recurring in the future.

5. Conclusion

The conclusions reached in this study show that the joint implementation of an optimized workspace design, balancing inventory in process, and incorporating an adapted clamping device are projected to significantly contribute to reducing assembly time in office furniture production processes, with a MOST-estimated improvement of 34.75% in operational efficiency. These projected results are consistent with the initial hypothesis, which proposed that the application of engineering techniques and time studies in an SME in the manufacturing sector could result in concrete production benefits, aligning with previous research reports that highlight the effectiveness of redesigning workstations and optimizing inventories in similar environments. It is noted that the reported time reduction is based on simulated (MOST-estimated) data; post-implementation measurement is recommended to validate and refine these projections.

In addition, the standardization and order generated by the application of lean manufacturing and 9S principles translate into a substantial improvement not only in productivity but also in safety and ergonomics for operators, which expands current knowledge about the comprehensive benefits of these methodologies in manufacturing SMEs. The methodological approach applied demonstrates that integrating traditional techniques with digital design technologies

(CAD) and practical tools (clamping fixtures) allows for adaptation to limited resources, a common feature in small and medium-sized enterprises. This aspect is rarely documented in traditional literature, providing a novel perspective on sustainability and resource ergonomics in emerging production contexts.

Although the study is limited in that it focuses on a specific type of furniture and a particular configuration, these restrictions allow for a detailed analysis that serves as a basis for future research aimed at validating and expanding these solutions to other similar sectors and production processes. It is recommended that the analysis be expanded with longitudinal evaluations and the inclusion of emerging technologies such as IoT for intelligent inventory management and real-time synchronization of production processes, which would further enhance the impact of the proposed improvements.

Finally, the explicit approach to human and organizational factors, such as the initial resistance to change detected in the interaction with operational staff, is highlighted as a critical aspect for the successful and sustainable implementation of innovations in SMEs. This dimension, often underestimated in similar studies, offers a valuable perspective for future interdisciplinary research that considers technological and cultural adaptation as fundamental pillars of sustainable industrial development. Overall, this research positions a replicable and adaptive model for the operational transformation of manufacturing SMEs.

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