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Lean Six Sigma with Value Stream Mapping in Industry 4.0 for Human-Centered Workstation Design

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Abstract: Many industries have successfully implemented the define-measure-analyze-improve-control (DMAIC) method of Lean Six Sigma to improve their production activities. Value stream mapping (VSM) for Industry 4.0 allows us to understand the current state of operations in order to plan future improvements. In this study, we propose an improvement model based on DMAIC with VSM 4.0 for a truck cooler manufacturer to improve the picking workstation design with a human-centered approach. We use the DMAIC method to analyze the project step by step. After identifying the root cause, we identified countermeasures to improve the productivity. To reduce human error, the project team adopted a human-centered approach and applied lean tools, such as visual management, error prevention, and waste analysis. As a result of this case study, the yield rate was improved from 98% to 100%, and the direct savings of the project amounted to EUR 3180, mainly due to the freeing up of space. A human-centered LSS framework is also presented as a novel contribution of this study.

Keywords: value stream mapping 4.0; Lean Six Sigma; picking workstation design; human-centered

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1. Introduction

Smart workstation design is critical for creating a healthy, comfortable, and productive workplace [1]. In response to disruptions in the global supply chains, automated workstations have been designed to replace labor and shorten working hours [2]. Lean Six Sigma (LSS) is a common strategy for improving operational excellence in manufacturing [3,4]. Lean emphasizes speed and waste, often referred to as efficiency, while Six Sigma emphasizes process variation reduction, often referred to as effectiveness [5]. LSS uses data and statistical analysis to identify the causes of fluctuations that lead to insufficient process outputs [6]. There are many examples of the LSS method's implementation in the manufacturing industry, including the roles of key personnel in all areas of business, such as production, finance, marketing, and even personal management. Chiarini [7] surveyed five European motorcycle part manufacturing companies using various lean tools and found that lean methods reduced waste and had positive environmental impacts. Singh and Rathi [8] conducted a comprehensive analysis of the barriers to LSS's implementation in small and medium-sized enterprises. Lean practices have not been implemented in various sectors in India [9]. However, some businesses have implemented and observed positive benefits of this method, mainly in terms of waste reduction and quality improvement. According to Jasti and Kodali [10], researchers should focus on building and testing novel ideas, including case studies and surveys that analyze academic findings from research on lean practices. Recently, it was found that 63.82% of empirical studies in the LSS literature use real data, and the process can be regulated and validated [11]. The majority of LSS applications in the industry are concentrated in manufacturing, healthcare, automotives, and electronics. Additionally, several articles focus on testing tools, obtaining benefits, and understanding success factors [12,13]. Several authors have discussed the analysis and exploration of key success factors of LSS in order to achieve effective quality management, organizational goals, objectives, and performance in industry [14–16]. Define-Measure-Analyze-Improve-Control (DMAIC) is the problem-solving approach that drives LSS. It is a five-phase method for addressing existing process problems based on a scientific method. In any work environment, continuous improvement can be correlated with the individual performing the activities in order to adapt the improvements to their needs [17]. It has recently been suggested that a human-centered approach can be integrated with the LSS principles [18].

Psomas [19] conducted a systematic literature review of lean manufacturing using a total of 214 articles and discussed a plethora of future research methods. Lobo Mesquita et al. [20] identified forms of integration between lean, Industry 4.0, and environmental sustainability, and showed how these three structures relate to the building of a framework that can help to manage industrial production processes. VSM is often regarded as the starting point for lean projects in the search for opportunities to optimize value and eliminate waste in the manufacturing process. A study by Jasti and Sharma [21] showed that the implementation of VSM had positive impacts in a lean manufacturing environment. VSM 4.0 is a recently developed, collaborative value stream tool for lean management in the context of Industry 4.0. Mapping, design and validate value streams are used to digitally plan improvement actions in order to reduce coordination times within the company. VSM 4.0 is a tool that enables company executives to engage in a series of structured discussions and executive decisions that enable continuous improvement. Numerous authors have provided particular strategies for certain businesses, despite the fact that this strategy is wide and versatile, spanning many industries [22,23].

In this article, we present a method combining the DMAIC approach in LSS and VSM 4.0 to design a human-centered workstation to support workers with intellectual disabilities. A case study is used to illustrate the application of the proposed method, which aims to enable the design of human-centered manufacturing workstations. Section 2 describes a review of VSM 4.0. Section 3 presents the LSS improvement model using VSM 4.0. Section 4 describes the current and future states of operational excellence in the case study company. The last section provides conclusions.

2. Literature Review

VSM creates product lines, records current states, envisions future states, integrates project pipelines, and transforms industrial activities. The map also allows users to focus on materials and information flows [24]. Traditional VSM is mainly used in a series of production lines that produce a single product or a single series of products. It now faces challenges in the big data environments that perform real-time data processing, visualization, and decision assistance. Therefore, it is not suitable for production sites with many products, unstable batches, and frequent line changes [25].

Recently, VSM was combined with Industry 4.0 technology to improve the traditional VSM. Both VSM 4.0 and Dynamic VSM (DVSM) can demonstrate the manufacturing performance of the entire process in real time through a data acquisition system. Meudt et al. [26] applied VSM 4.0 to detect waste and loss in information flows. Hartmann et al. [27] provided steps for designing VSM 4.0 and a new understanding of the information in the value stream. DVSM is based on the integration of traditional VSM and Industry 4.0 technology, connecting production factors such as equipment, workers, and materials. Ramadan et al. [28] combined RFID technology with VSM and proposed a DVSM implementation framework to track and visualize the development cost of a single product. Huang et al. [29] proposed a multi-layer DVSM that combines traditional VSM with a multi-agent system based on cyber-physical system (CPS) technology. An agent can automatically collect data near the site in order to display changes in key metrics related to materials and information flows in a multi-stage production process, either in real time or near-real time. Balaji et al. [25] introduced an integrated model of the internet of things (IoT) and

VSM to collect shop floor data and monitor on-site status in real time, helping managers to quickly carry out improvement activities based on experience. Schoeman et al. [30] applied VSM to visualize and analyze waste flows of an iron and steel company in order to achieve an environmentally responsible zero-waste environment. Qin and Liu [31] used VSM to improve the entire e-commerce supply chain process for an amazon retailer.

Guo et al. [32] proposed a hybrid approach combining VSM and DMAIC to overcome the practical implementation of a VSM diagnostic tools and verify the performance throughout an air conditioner assembly line. Salah and Rahim [33] identified waste in the current VSM in the DMAIC program and improved and developed it into the future VSM. DMAIC is a framework suitable for integrating lean practices because it is a problem-structuring tool, providing empirical results that can be used to eliminate waste in structured and semi-structured cases [34]. According to Gupta and Jain [35], every lean tool plays a unique role in specific problems. We must use each tool to understand when, where, why, and how to produce a successful DMAIC process. Most lean tools belong to the improvement and control phases of DMAIC, but once an opportunity has been identified, there is no reason not to use them immediately [36]. Thus, more studies based on the integration of LSS and VSM 4.0 are required.

The potential to improve productivity by implementing LSS and VSM 4.0 using a human-centered approach is worth exploring. An essential aspect of continuous improvement is the inclusion of a human-centered design, as traditional LSS interventions, while attempting to maximize productivity by minimizing resources, often ignore human constraints and needs. When humans are integrated into continuous improvement activities, they provide a whole new dimension in the improvement process and a new perspective on its design [37]. Therefore, to ensure increased productivity and improved working conditions, a continuous improvement process should be implemented whilst simultaneously using a human-centered LSS approach. To achieve this, a comprehensive methodological framework is required.

3. Research Method

Lean and Six Sigma are two compatible problem-solving methods [38]. Lean typically starts by developing an understanding of the customer's added value and then uses VSM to examine the process in detail. When VSM identifies criticalities in process steps [22], Six Sigma provides a data-driven analytical approach to define and quantify the error types. LSS specifies an improvement process called DMAIC. Figure 1 depicts the LSS improvement model using VSM 4.0.

In the DMAIC process, VSM 4.0 is used in the define and improve phases. First, in the define phase, team members write a project charter detailing the project goals and problem statement and use VSM 4.0 to map the process components and process boundaries. In addition, a project management team is assigned to determine the roles and responsibilities and develop the project timeline. Next, in the measure phase, the project team members assess the current situation in order to gather information. Before entering the analyze phase, we must measure the performance metrics of the process.

During the analyze phase, the project team members identify potential causes and evaluate them through hypothesis testing and other explanatory analyses. Some ideas are also generated and must be validated before they can be used in the improve phase. For the next phase of improve, team members plan how they will use VSM 4.0 for a full implementation, select and use tools to eliminate waste, and update the performance metrics of the process as needed. Finally, in the control phase, the team members develop a plan for monitoring and transferring responsibilities to ensure continued success. Additionally, the team finalizes the business case using risk and financial analyses. At each of these phases, tools are used to ensure the correct execution of the picking workstation design, as shown in Table 1.

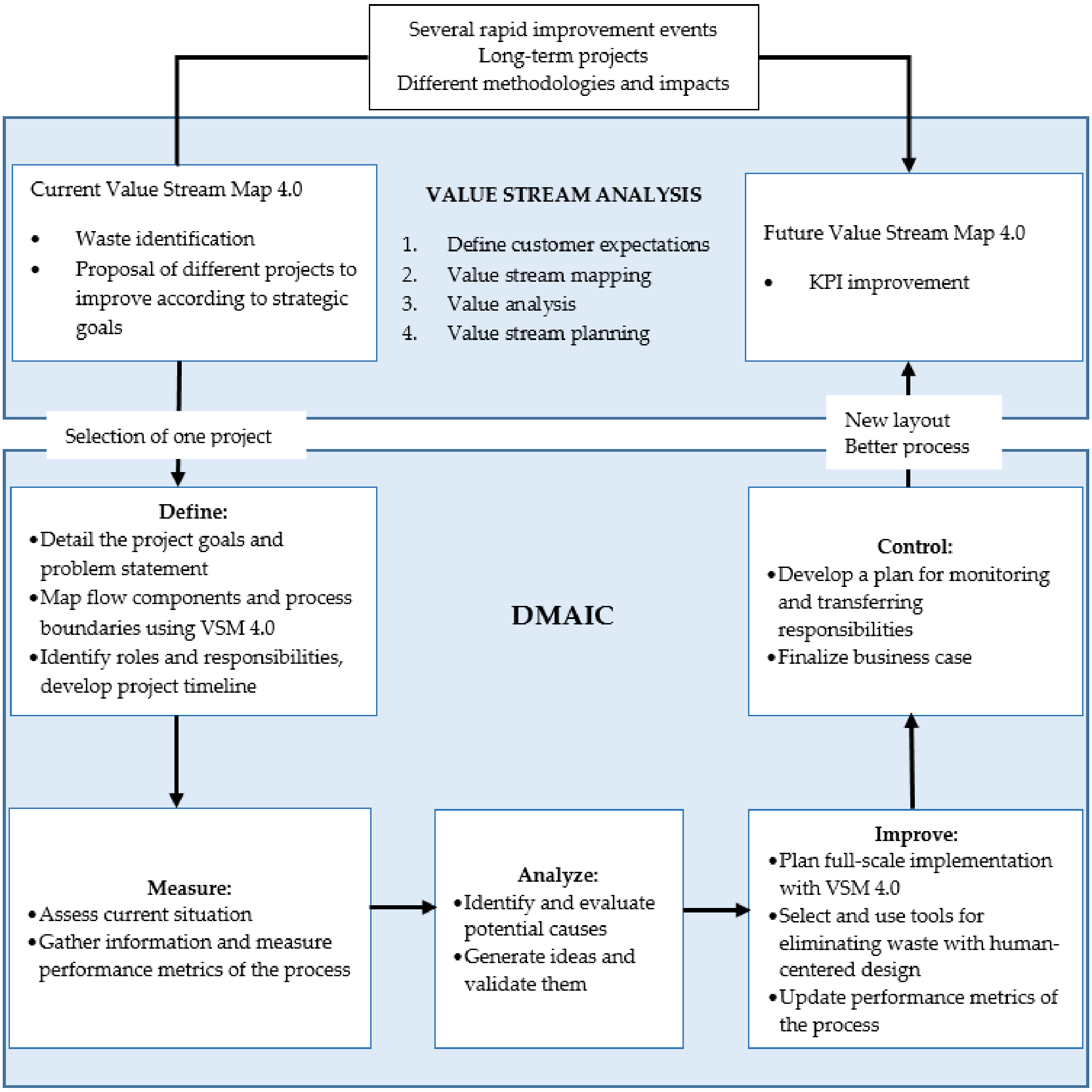

Figure 1. An improvement model of LSS with VSM 4.0.

Table 1. DMAIC approach for the picking workstation design.

Phase	Tools	Activities
Define	VSM 4.0 (current state) Project charter SIPOC diagram Gemba	1. Establish team 2. Assign specific role 3. Create project timeline
Measure	Key performance indicator (KPI) Data visualization	1. Describe process 2. Collect data
Analyze	5 Whys	Identify problem and solution
Improve	Kaizen events VSM 4.0 (future state)	1. Relocate workstation 2. Codify parts and kits

Table 1. *Cont.*

Phase	Tools	Activities
		3. Design identification cards, templates, and trays 4. Create job breakdown sheets
Control	Brainstorming the risks and countermeasures	1. Risk analysis 2. Financial analysis

SIPOC stands for suppliers, inputs, process, outputs, customers.

4. Case Study

The case company, called Company T (TC), is located in Spain. It is a world leader with operations on all continents and authorized distribution in 75 countries. TC manufactures truck coolers to ensure world-class quality and promote a diverse culture. The company's managers found, using the annual value stream analysis (VSA), that they needed to respond faster in order to deliver higher quality products to customers, and they identified certain gaps in the manufacturing process. Among the three parallel picking stations at the ends of the three assembly lines, one of the gaps was related to the preparation of bags with distinct sets of electrical components in the style of a typical picking station. Managers found that there was a lot of waste in the process, a lack of inventory management, and frequent customer complaints. Thus, they devised the idea of combining three workstations into one so that they could hire a full-time employee to prepare the small bags with the electronics. Furthermore, because of their strong dedication to diversity, the company seized the opportunity to integrate people with intellectual disabilities into the new workstations. Therefore, the entire workstation had to be designed with great attention to detail, visual cues, and intuitive operation.

The VSA developed certain management agreements, including specific goals and KPIs for the next 12 months, in order to improve the process. These metrics are linked to the six performance indicators listed in Table 2 (safety, quality, delivery, inventory, employee engagement, and growth), as well as statuses and their projects. After reviewing the VSM, the managers identified several contingencies for identifying opportunities for the improvement of the process. A striking highlight was the kit preparation workstation. The cooling unit has three assembly lines, each with a picking station. Each unit takes less than a minute to run. The workers at this workstation pack electronic components into small plastic bags. These components can be used to install cooling units in the customers' trucks. The workstation is subject to the following issues, including the triple inventory points. Since the amount of work required is less than one cycle time, workers must constantly switch between workstations, and they perform other work at the same time. Some customers complained that the components were inefficient for installing the equipment and that the process was inefficient due to inappropriate workstations that are poorly designed for the material flow, ergonomics, and 5S systems. It was determined that combining three workstations into one would provide benefits such as providing a sufficient workload for the 4–5 h shifts, reducing the total inventory, because there is only one point of operation, freeing up more space in the production line, increasing production, and ensuring a calmer environment. At the beginning of the line, to optimize the flow, and because there is no need to change the workstations to the same cell in the line, the overall performance of the line workers was improved.

After the VSA, several project ideas can emerge. Using the DMAIC process is useful for running select projects, as it provides a clear roadmap. This case study explains the DMAIC problem-solving process and all the important aspects of designing this unique workstation. The selected project included a person with an intellectual disability because TC's culture emphasizes community and sustainable development. The company has negotiated an arrangement with AUR, a non-profit organization that helps people with mild intellectual disabilities to find work. Now is the perfect time to build a new picking station, including people with intellectual disabilities, because the labor is simple, safe, and not positioned in the assembly line. As a result, a prospective employee was invited in, a contract with TC was signed, and work began on a new workstation design. This work has to be based on a human-centered strategy based on lean principles; therefore, it starts with attempts to gain a good understanding of people's abilities, speeds of work, and aspirations. Since the prospective employee was due to start work in 21 days, this became the deadline for the project. The DMAIC flow in this case study is shown below.

Table 2. Performance metric review.

Indicator	Safety	Quality	Delivery	Inventories	Employee Engagement	Growth
Current state	No accident in the past 10 years	There is no systematic categorizing of problems	A total of 2–3 days in Southern Europe, 1 week in Northern Europe, 3 weeks in the Middle East, 4 weeks in America	More than 75% of the references had a delivery time of less than three days	Recently, there has been a decrease in employee engagement	Around 30% of the weeks show operation at full capacity
KPI	Number of workdays missed due to working accidents	The number of warrantee requests received within the first six months after delivery	Percentage of units delivered on time	Percentage of the cost of inventories reduced from the current level	Employees' average satisfaction ratings	Maximum capacity
Projects	Keep track of minor bolt and screw inventories	Create an effective diagnosis and classification system	Improve assembly line capability and design a workstation efficiently	Unify workstations and sites along the line where materials are held	Improve line balance and the ability to react and adjust production levels quickly	Restructure the lines and unify some identical workstations in each line

4.1. Define

At the end of each assembly line, there are three picking stations for the preparation of bags with the electronic components (kits). These stations take up a lot of space and have many stock outages. Moreover, workers underperformed due to having to fact that they had to change between activities and the picking workstation waste, which only required 1/10 of their cycle time. Defects related to misidentification occurred frequently, and the missing parts could lead to unforeseen downtime. Figure 2 depicts the current VSM 4.0. If the space and waste of the three production lines were used more efficiently, the factory would save time and space, improve the quality, and reduce the inventory. This time and space could be used to add more workers to the assembly line and create more units. The project timeline was 21 days and included all stages of the DMAIC process (see Figure 3). The project began when the company chose to start the DMAIC process to build a new workstation and ended when the workers started work. The control phase lasted significantly longer, at least three months, to ensure that the quality standards were met. Furthermore, the learning process had to be tracked according to the self-interests of the workers.

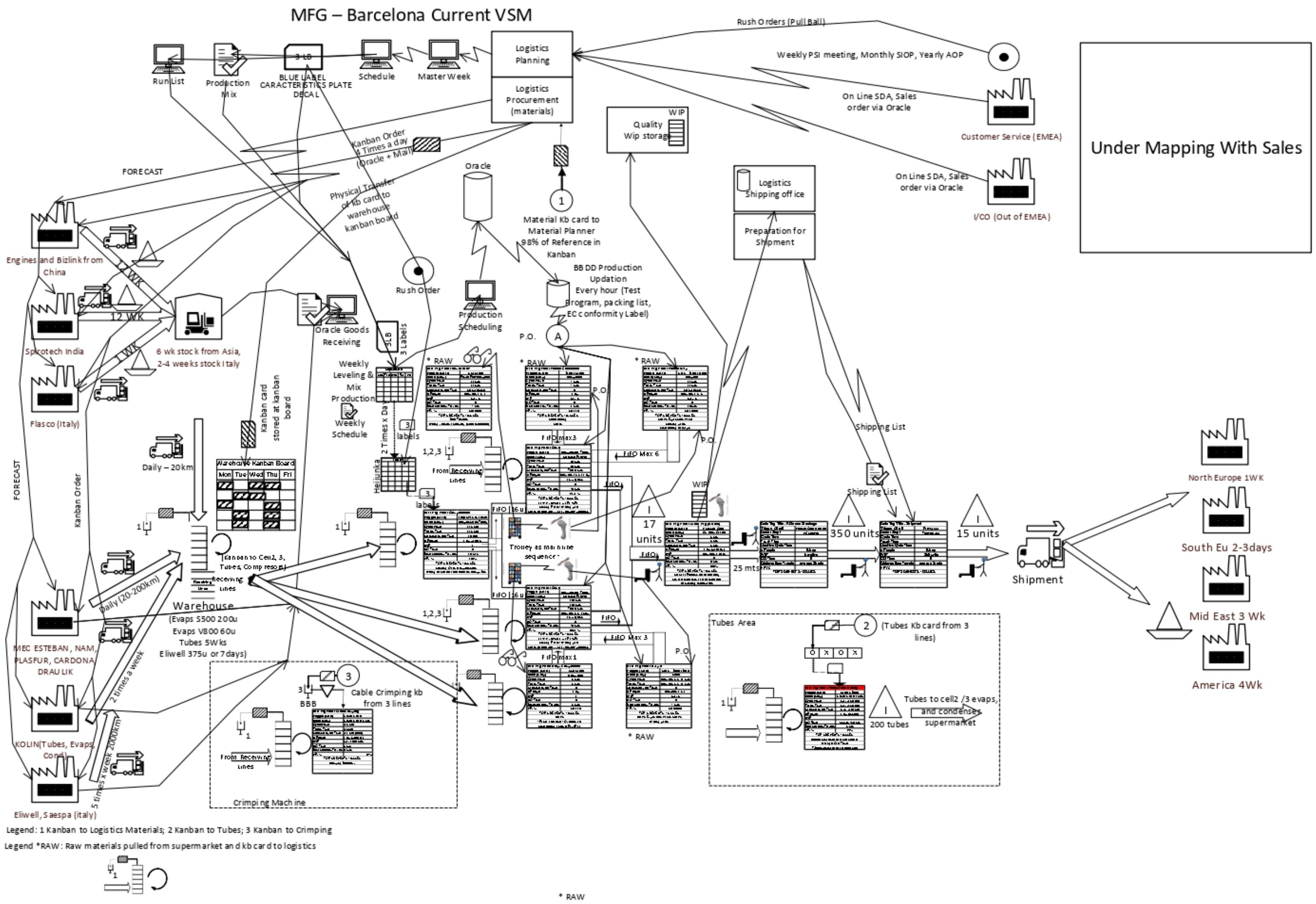

Figure 2. Current VSM 4.0.

Phase	Activity	Day																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
D, M	Understand and measure the current state	3 days																				
A	Gather ideas for improvement			2days																		
	Validate ideas with experiments					4 days																
I	Requirements and items list					2days																
	Design tags and templates									3 days												
	Program devices												2 days									
	Design material flow												5 days									
	Start construction of the new workstation									8 days												
C	Test with the worker																	5 days				

Figure 3. Project timeline.

4.2. Measure

During this phase, the current situation was assessed, and waste was identified and defined. The team first determined what information needed to be gathered and realized that defects were not a quality issue, because the installer had the relevant references; thus, they were fixed within less than a week. However, defects have an impact on delivery, as the customer is not able to utilize the equipment until the installation is complete. Therefore, any defect in the kit had to be considered a delivery issue. The team obtained data by analyzing the last 3000 shipments and found that 97.8% of the defective kits occurred due to missing parts (76%), misidentification (18%), and defective parts (6%). Each production line was assigned a worker who was responsible for the kit preparation. Certain jobs were assigned by this worker to units five or six meters away from the picking station. After completing the mission, the process started with the verification of the unit name and extended to the time when the kit was brought to the unit. Table 3 describes the process and the averages for the types and times of four different workers. Specifically, the process was affected by the following four types of waste:

(1) The worker uses hand movements (1,7) to travel from their current workplace to the picking workstation and back. However, because the worker is continually changing jobs, this mobility wastes time and reduces productivity and concentration.
(2) Picking up (4) parts is inefficient, since workers are continually comparing the panel to the materials.
(3) Mislabeling (6) is common due to the presence of tags from several kits on the table. As a result, the worker must pay close attention to picking up the correct one and comparing it to the unit.
(4) Movement due to an insufficient inventory (8) occurs with every 200 kits, or every two production days. The worker has to leave the line for about two minutes to gather extra material for the kits when the boxes containing parts run out of material.

Table 3. Details of the process description.

No.	Action Name	Type	Rounded Time (s)
1	Going to the workstation after leaving the unit	Movement (5 m)	10
2	Verifying the name of the unit that is being prepared	Visual inspection	2
3	Finding barcodes	Hand movement	4
4	Picking an empty bag	Hand movement	2
5	Finding appropriate objects	Hand movement × 10	3 × 10
6	Tagging the bag	Hand movement	5
7	Return to the unit with the kit	Movement (5 m)	10

Table 3. *Cont.*

No.	Action Name	Type	Rounded Time (s)
		TOTAL	63
8 *	Going to a different place to search for missing components	Movement	120

* is not a part of the process; it occurs when there is a shortage of materials.

4.3. Analyze

After considering the measurements and data gathered, the team proceeded to investigate each defect and determine the root cause. At this stage, a hypothesis is developed to identify the sources of different error types, bottlenecks, and sources of variation. To evaluate the hypothesis, we used five "why" analyses and a quick test. The five main problems observed during the measure phase and their five "why" analyses are summarized, together with the suggested solutions, in Table 4.

Table 4. Five whys analysis of the observed problems.

Waste	Movement to and from the Picking Workstation	Slow Pick-Up Process	Mislabeling	Missing Parts	The Movement Caused by the Inventory Break
Problem	Changing workstations wastes a lot of time for the worker	Picking up materials is a time-consuming and wasteful activity	The barcode stickers on the kits do not identify them well	Many of the kits are incomplete	The worker must leave the line in order to obtain more material
1st Why	A worker must prepare a kit every time a machine is due to be packaged	The worker must keep an eye on the panel at all times	A worker inserts an incorrect barcode	They were not placed inside the bag by the worker	One of the components was depleted
2nd Why	The main assembly process is serially integrated with the kits	There is no easy way to tell what is in each kit	There are many barcodes on the table, and they all look the same	The worker forgot to bring a specific item	The material levels are insufficient for allowing for frequent replenishment
3rd Why	One-piece flow is the production method used	In the boxes, there are no visual aids	Workers have already printed many of them	The worker has no means of knowing if the object was already inside	Every part has three distinct points, and there is not enough room in the workstation for an additional secondary box with parts
4th Why		The boxes come from the resupply, which is not visually altered	The printer is a long distance away, and employees rarely visit it	The worker arranges the items one by one	
5th Why				They have no place to be visualized	
Solution	Remove the process off the mainline and work in batches. The process will become more agile with repetition	Visual identifications on boxes should be visible without having to look at the panel	Tags with various barcodes should not coexist on the table. The printer should be placed close to the table, and only the necessary documents should be printed	Before placing items in the bag, they should all be arranged on a tray to ensure that none are missing	Combine the three inventory points and make room for more component boxes next to the current ones

4.4. Improve

This phase allows us to test the implementation of the idea and the realization of the project. Because it covers all aspects of the workstation design, installation, and worker participation, the improvement phase is the most thorough. Since LSS is a human-centered approach, it aims to reduce human error by involving workers in the process [39]. Therefore, considering their intellectual disability, it was necessary to focus on the workers' needs and test the ideas for improvement in participation with them. In this study, an improvement phase using VSM 4.0 was implemented for the following reasons:

(1) The ability of the worker. Project team members concluded that, if the process was well-structured, simplified, and predictable, workers would be able to complete the work. Therefore, the team established a path that is fully integrated with the workers. The path is designed to last for two months, starting and ending every day for 3 and 6 h successively.

(2) The workstation location. In addition to safety managers and work instructors, the team opted to move the workstations further from the production line, simplifying the material flow. Four types of waste identified in the measure phase were taken into consideration when rearranging the location. The location is at the beginning of the line and the kit is to remain with the structure. The new locations marked with w in the factory layout (Figure 4) illustrate how the workers can be placed at the beginning and center of the production lines in order to distribute the kits to the ends of the three assembly lines. The black arrows in Figure 4 show the incoming and outgoing material flows.

(3) Part and kit codes. To speed up the picking process, all parts and kits required simple coding. The team chose to use symbols to code the parts (Figure 5) and colors to code the kits (Figure 6). Since some parts are already easily identifiable, they do not have any associated symbols. A symbol with an alternate reference number is placed next to the part image. The kits are color-coded and have letters to name them. With this simplification of the parts and kits, templates and tags could be designed effectively.

(4) Templates and trays. The template in Figure 7 depicts the actual dimensions used to identify the surrounding colors of the kit and provide an image of the part, so that workers can easily view the part on the top of the picture. There are tapes behind the template for fixing the metal tray. Figure 8 shows a tray with a funnel placed below it at a low height to prevent parts from falling out of the tray.

(5) Identification card. The appearance of the card allows for quick viewing for the selection of parts. It was deemed that the cards should have a visible picture of the parts and symbols and include colors and quantities to indicate to the workers which kit they correspond to. Figure 9 illustrates how the templates and cards work together.

(6) Box location and size. All parts are divided into three sizes of box: small, medium, and large. The locations of the boxes are sorted according to the frequency of their replenishment: very frequent, common, and rare. Other important considerations are that all boxes must be within reach of the worker (no walking required) and that boxes containing more frequently used items should be in the center. A complete image of the workstation is shown in Figure 10.

(7) Kanban and first-in, first-out (FIFO) order tracking. The team decided to implement a FIFO rail, where the production manager hung Kanban cards according to the production needs. In addition, barcodes on the Kanban cards are to be scanned to identify the bags and boxes where the kits are to be stored in the production line.

(8) Scan and print barcode tags on site. After the worker picked up the Kanban card, they scanned the barcode on the Kanban card to obtain the tag for the automatic printer. The purpose of this process is to avoid mislabeling, as Poka-Yoke prevents workers from making mistakes. Workers fill the bag with the appropriate pieces until all tags are used up, after the tags are created and placed next to the tray in the preparation kit. When all the tags in a batch are used up, workers place a box of kits into the outbox, remove the next Kanban card, and start a new batch.

(9) Outbox. Workers can find boxes with batches of kits on the right side of the map. Replenishers deliver full boxes to the line every hour. Inside the box, there is a level surface and a ramp to place the finished boxes on, and there is space for storing the next batch of empty boxes.

(10) Work breakdown sheet. The team created a work breakdown sheet detailing all the functions of the workstation, as shown in Figures 11 and 12. These two sheets refer to the kit preparation and material replenishment processes, which are required by the picking station.

4.5. Control

In this phase, the team assessed the workstation's effectiveness, as well as the workers' learning paths and progress. Three templates had errors identified within the first week. A control plan enables quality control and ensures that defect-free kits reach the customers. Workers can complete batches on the same day because the templates are easily recreated. As shown in Table 5, some risks and countermeasures for their avoidance were observed during the first month of implementation. The team developed an adaptation plan before the workers started work, but the plan was adjusted based on performance. Workers worked three hours per day and three days per week for the first two weeks, which was not enough to supply all he factories with a kit. After evaluating the efficiency, the company expanded the working hours to 4 h per day and 4 days per week in order to complete all the required kits. Table 6 shows the adjusted planned and actual production kit quantities. In the first two weeks, the kit only had defects related to external issues, such as labeling confusion, misplaced items, and insufficient materials. Once all the issues are corrected, no errors were logged for the next four months, which means that the first pass yield (FPY) of the improved workstation increased from 98% to 100%. In the end, the team decided to hire full-time staff (6 h per day, 5 days per week) and schedule another future project to increase the workload of the workstations and other similar tasks.

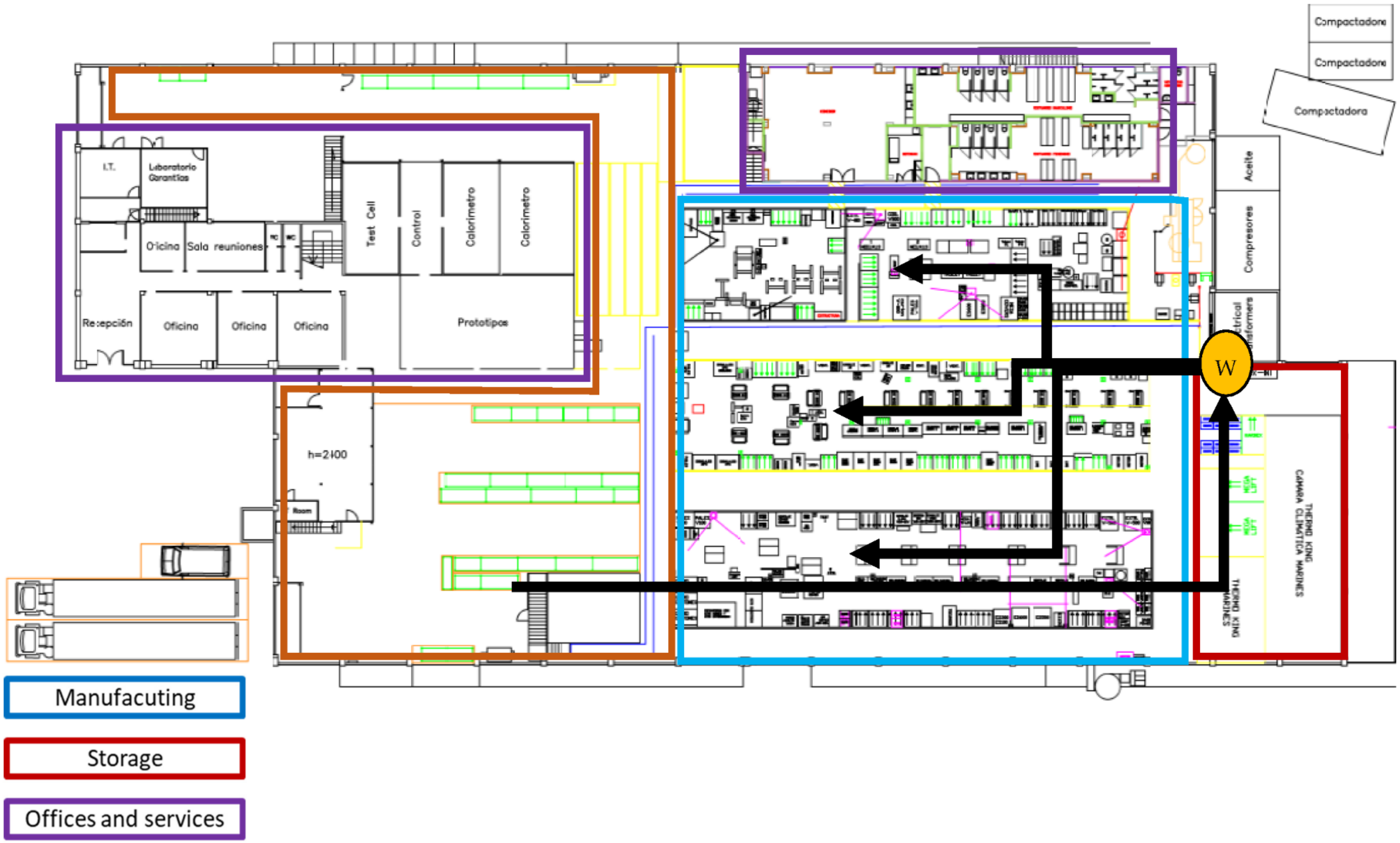

Figure 4. New location for the kit preparation workstation.

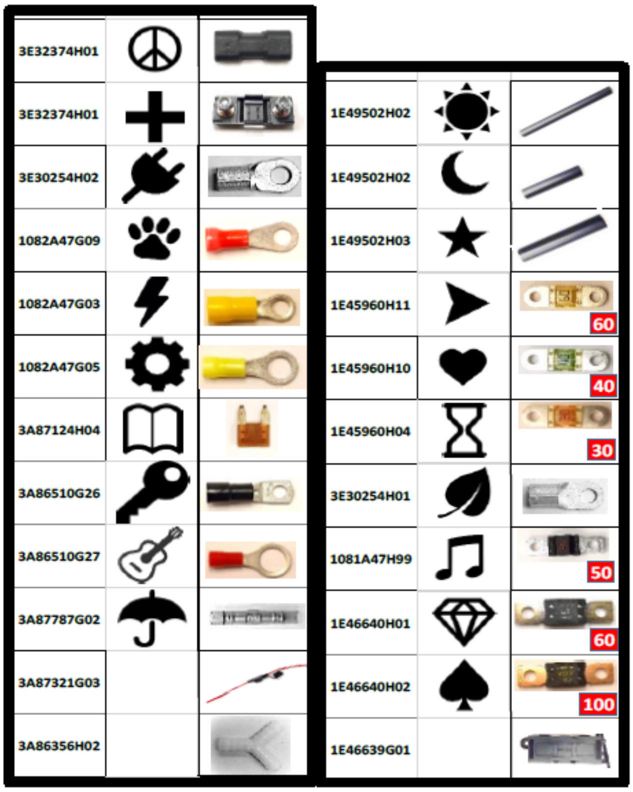

Figure 5. Relation of references, symbols, and parts.

CEL 3				CEL 1		CEL 2			
A	B	C	D	E	F	G	H	I	J
V500	V500 SPC	B100 12V	B100 24V	V800 MAX50 V800 SPC	V800	CE	C450	V100 V200S	V200 V300
KIT SPCL 50A -1Y V500/V600	KIT SPCL 60A -2Y V500			KIT SPCL 2X30A - 2Y	KIT SPCL 2X30A - 1Y	KIT SPCL 30A -1Y CE	KIT SPCL 40A -1Y CE	KIT SPCL 30A -0Y	KIT SPCL 40A -1Y
1E17546 G09	1E17546 G10	1E40098 G01	1E40098 G02	1E17546 G11	1E17546 G12	1E17546 G13	1E40098 G14	1E17546 G15	1E17546 G16

Figure 6. Relationship between references, colors, and kits.

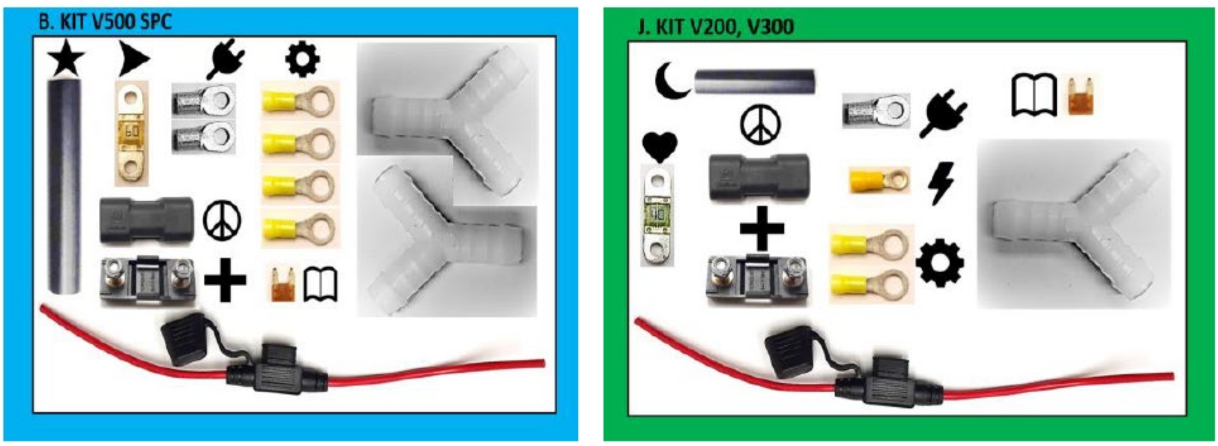

Figure 7. Templates with colors, objects, and symbols.

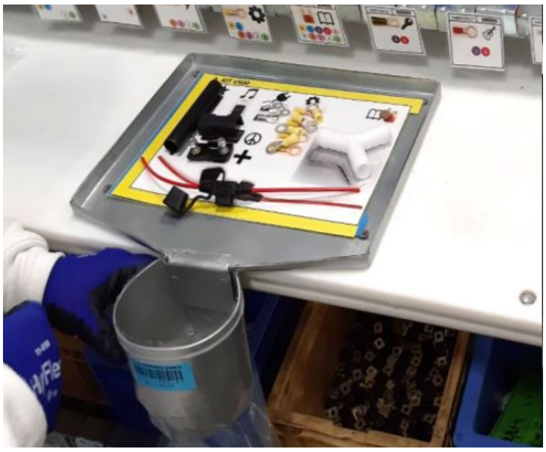

Figure 8. Place the magnetic template on a metal tray.

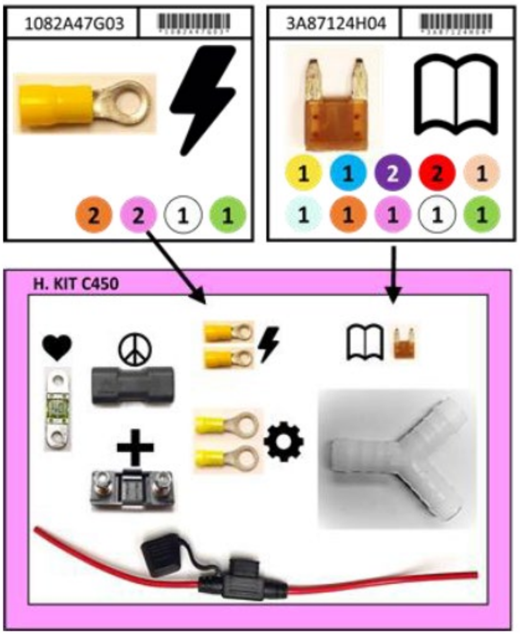

Figure 9. Correspondence between the identification cards and templates.

Figure 10. Picking workstation.

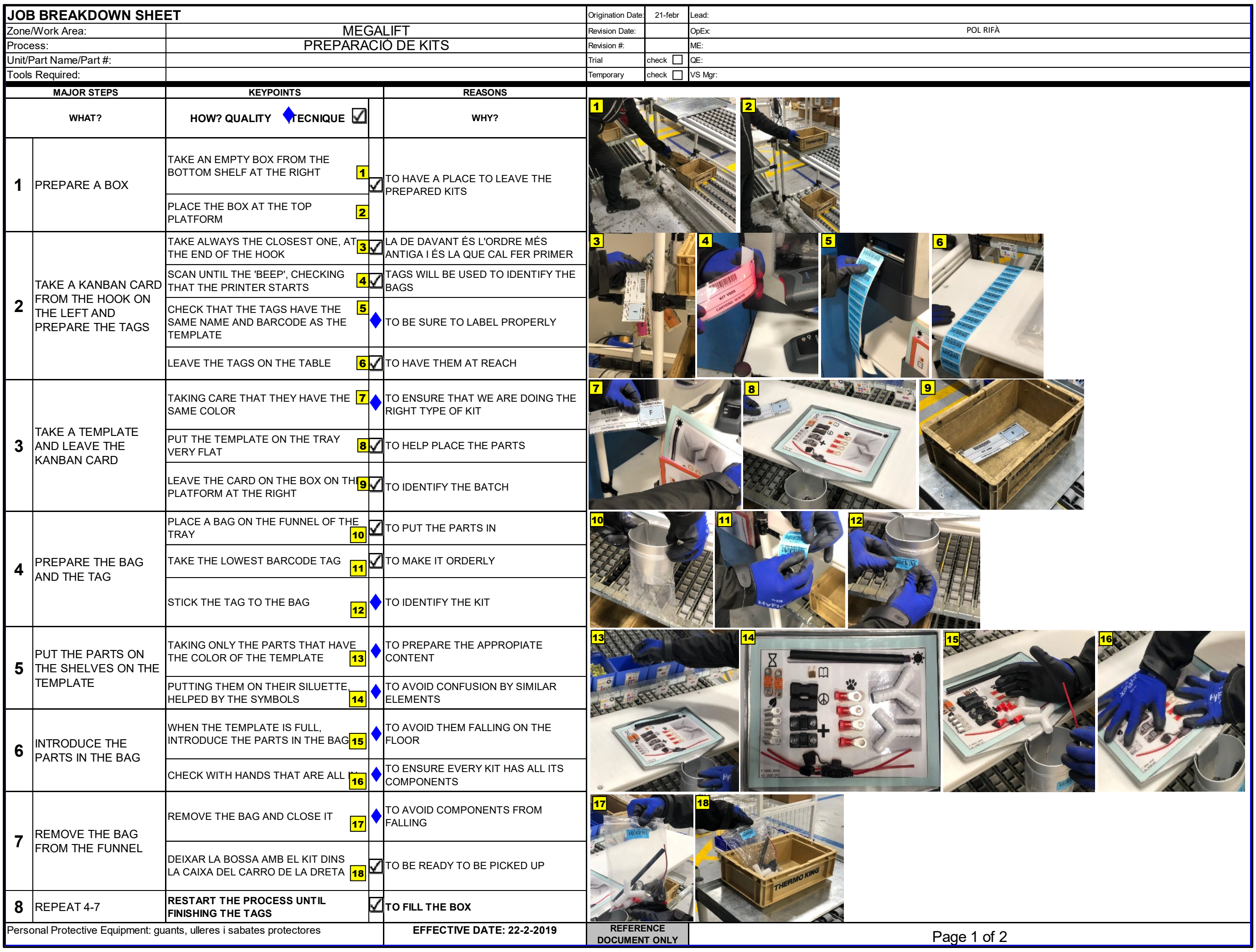

Figure 11. Work breakdown sheet of the kit preparation.

Table 5. Risks and countermeasures in the first month of implementation.

Risk	Countermeasure
The workstation does not include all of the factory's kits	Other picking workstations continue to operate as usual
The template and cards are most likely incorrect	During the first week, small quantities of all the different kits are used and another worker double-checks the quality of the kits
Any discomfort experienced by the worker as a result of the workstation improvements	The worker's motions are studied in real time by the safety department in order to detect any weariness or potentially harmful movements
Replenishers are not assigned to the new material locations	A regular reminder to monitor the workstation is issued over the first two weeks
The worker is not able to deliver satisfactory results	During the first month, the worker keeps track of the number and type of kits created

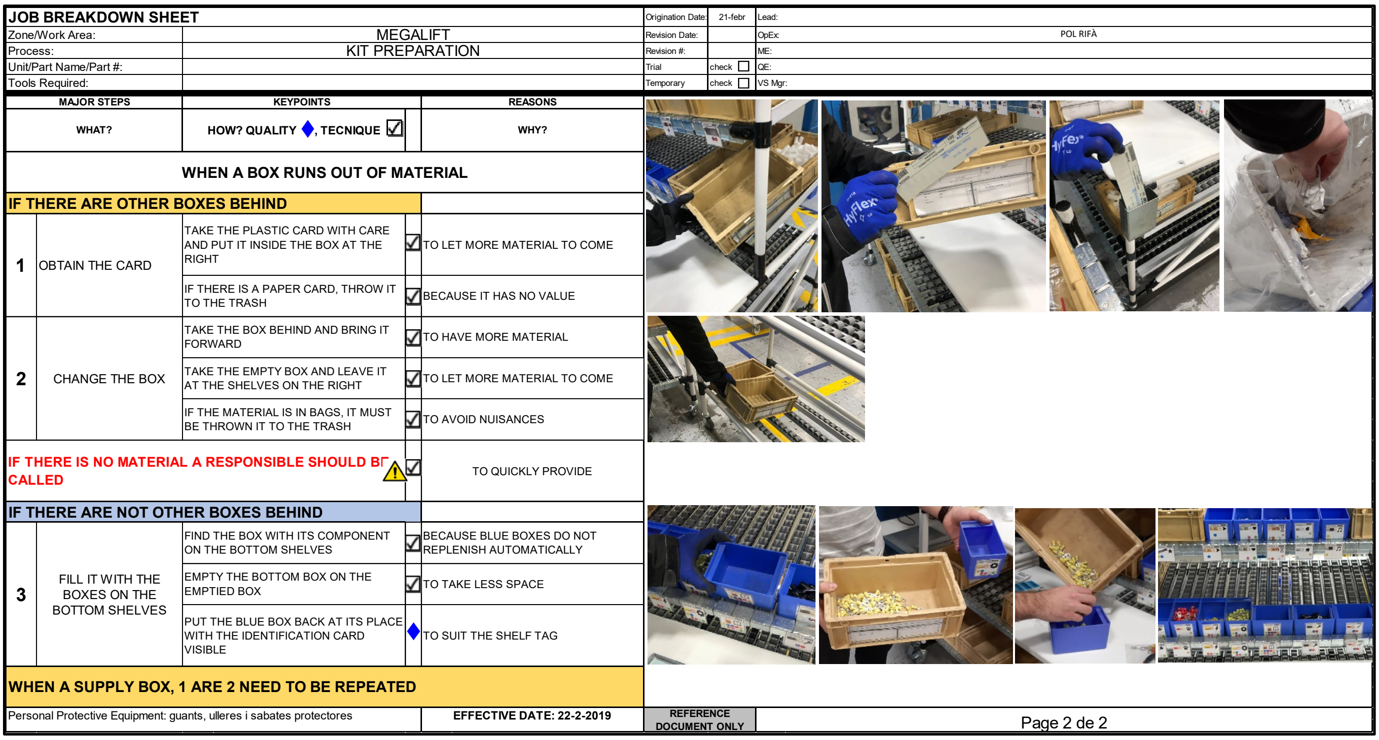

Figure 12. Work breakdown sheet of the material replenishment.

Table 6. Plan for the first month of adaptation.

State	Hours/Day	Week Day	1 1	2	3	2 4	5	6	3 7	8	9	10	4 11	12	13	14	5 15	16	17	18
Taught by instructor	3		56	75																
Surveillance at work	3				70	83	95	90												
Working alone, quality checks	4								133	145	140	135	152	142	135	137				
Normal workload	4																160	153	158	140
		Total		201			268			553					566			611		
Kits/hour			19	25	23	28	32	30	33	36	35	34	38	36	34	34	40	38	40	35

4.6. Financial Effect

The cost analysis of the project is detailed in Table 7. The most relevant suggestion is the addition of another person to the workforce, but the new incorporation of the technology is cheaper than another salaried employee. As the goal was not a cost reduction, this project made some resources available to increase the production, mainly in terms of space and time.

Table 7. Cost analysis of the project.

Description	Item	Cost (EUR)
Cost of the materials for the workstation design	Bench, computer, printer	4.000
Salaried employees cost of project execution	60 h (EUR 30/h)	1.800
Cost of additional employee (within the inclusion plan)	Part-time contract	1.200/month

The impacts of the process can be seen by observing the following indicators:

1. Space: free up 8 m^2, transitioning from 11 m^2 in three different locations to 3 m^2 in one location.
2. Productivity: a 63 s bottleneck for three production lines, enabling increased production.
3. Quality: increase the yield rate from 98% to 100%.
4. Inventory: transition from three places to one place, so that the volume is reduced by 40%. Initial cost: EUR 2200.

The direct savings of the project amounted to EUR 3180, mainly due to the freeing up of space (see Table 8). In the long term, the time saved (at 2.000 units/month) and quality claims (6 claims/month) were estimated to save EUR 100/month. It is difficult to estimate these costs, but the most relevant impacts of the project relate to inclusiveness, space, and predictability.

Table 8. Benefits and savings of the project.

Impact	Item	Savings (EUR)
Space	8 m^2 freed	8.000
Assembly time in the line	63 s/unit	0.4/unit
Inventory reduction	40% of EUR 2200	880
Quality claims by missing parts	5 claims/month	500/month

4.7. Human-Centered LSS Framework

For organizations today, LSS is the most popular methodology for streamlining operations and improving customer satisfaction. Although LSS has many expected benefits, it has one major unintended consequence. Due to its focus on process simplification, employees often feel marginalized. By combining the powerful tools and techniques of LSS with those available using a human-centered approach, as shown in Figure 13, the raised issues can be addressed. This integration enables organizations to engage all different types of employees, partners, and customers in a more effective and productive manner. Integrating LSS tools and technology with a human-centered design and management involves: (1) utilizing VSM to create a more powerful and insightful tool for better understanding current frictions with customers, business partners, or employees; (2) using the customer voice to develop the customer mental model; and (3) developing an employee mental model for each key employee role in the re-engineering business process. This will ensure that the process guides them on a journey that leads to a new business process. In doing so, the employees will be ready, willing, and able to serve customers and business partners as needed. LSS adopts the perspective that any effort to improve systems, processes, products, or services must begin with the customer and the people performing the work. The tools and mindset of a human-centered approach can support performance improvements and take them to the next level in order to understand ambiguous challenges and develop innovative solutions to address them.

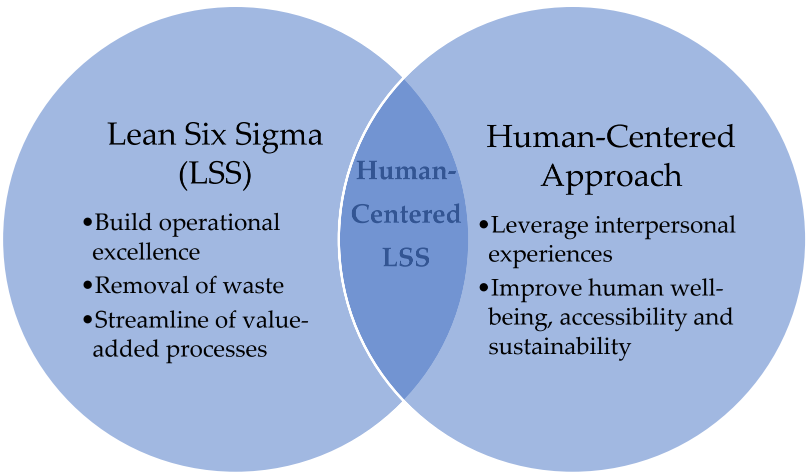

Figure 13. Human-centered LSS framework.

5. Conclusions

Adopting a complementary LSS approach expands the toolbox and offers the prospect of continuous improvement for many industries that have already implemented lean principles. Using VSM 4.0 as a tool, managers can focus on value and develop appropriately, and changes in the production processes can be quickly detected and planned. LSS's DMAIC strategy is a holistic approach that ensures a thorough understanding of potential problems and continuous improvement. We proposed an improvement model based on DMAIC and VSM 4.0 for a truck cooler manufacturer to improve the picking workstation design with a human-centered approach.

The case study provided a step-by-step process framework for, and in-depth analysis of, the implementation of our proposed improvement model. This model allows the company to generate available space on the assembly lines, thereby enhancing the ability to assemble more units and, of course, productivity. In addition, the electrical kit used for the installation achieved 100% FPY, successfully enabling the participation of mentally handicapped workers and raising the company's standards to provide better workstations. The direct savings of the project amounted to EUR 3180, mainly due to the freeing up of space. After the project was completed, not only was the financial performance satisfactory, but the planning capabilities and employee engagement were also improved, and the quality complaints, costs, and deliveries were reduced.

The presented paper is based on a single case study, and the results are limited to this company only. However, the approach of this paper offers a generic learning perspective. Through the effective application of LSS quality initiatives, the means by which the direct savings of the project could be obtained have been demonstrated. Thus, this paper could serve as a unique roadmap for practitioners and academics to improve the material productivity in terms of both product and process.

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