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IMPROVEMENT PROPOSAL FOR A COMPANY IN THE METALLURGICAL SECTOR: AN APPLICATION OF DMAIC CONSIDERING ERGONOMICS/HUMAN FACTORS

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Abstract

The industry has undergone an evolution, moving from personalized artisanal work to mass production with high yields, quality and a focus on low costs. However, throughout this process, human beings ceased to be the main focus and became merely a supporting element in terms of cost, quality and deadlines. As a result, the search for greater productivity ended up leaving human beings in a secondary role in companies. In this context, the aim was to highlight human beings and improve the accuracy of the inventory process in a metalworking company in the metropolitan region of Curitiba. To this end, the DMAIC method was applied in conjunction with the AMT method. The result of the project consists of an improved inventory process, taking into account the reality of the company. During the application of the DMAIC cycle, the AMT method was used to gather the possible root causes of the opportunities raised. Furthermore, with the AMT, employee dissatisfaction with the organizational climate and leadership was observed. In addition, high levels of discomfort and pain due to repetitive work were identified. With the causes defined, solutions were sought for the problems. These were analyzed, prioritized and tested. With the implementation of the solutions, there was a 1.68 percentage point increase in the accuracy of the inventory process, reaching 94.68% (target of 95%). To keep the project sustainable, a control plan was developed with actions and recommendations, in a cycle of continuous improvement.

Keywords: DMAIC; Lean; Human Factors; Ergonomics; AMT Method.

1. INTRODUCTION

The valorization of human factors has gained more and more prominence in the industrial sector since individuals have been increasingly recognized in different stages of company processes, from product development to after-sales, becoming fundamental parts within the production system (BITENCOURT et al., 2020).

It is not new that the balance between organizations, technologies and human resources has been studied. For more than 70 years, the Tavistock Institute has studied the concept of the

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socio-technical system that addresses the balance of these three factors (THE TAVISTOCK INSTITUTE, 2022). However, over time, the recognition of the value of the work done by employees in a company, which was previously indisputable, has been gradually neglected in favor of prioritizing other aspects, such as productivity and cost reduction.

When talking about Lean, the first idea that comes to mind is cost reduction and customer prioritization. Even in its most famous application, the combination of Lean and Six Sigma is idealized by Motorola in 1986, focusing on product quality and using the cycle for continuous improvement, DMAIC (*Define, Measure, Analyze, Improve and Control*); known as *Lean & Six Sigma*, there is no emphasis on the importance of human beings and their well-being in production processes, despite being present in all stages of this process.

Within the application of *Lean & Six Sigma* there is the standardization of tasks, elimination of unnecessary activities and improvement of the workflow, which often does not directly consider the needs and skills of the workers.

However, over time, there has been an evolution in the thinking of companies, with a growing understanding that human factors play a crucial role in the efficiency and quality of processes. This context highlights the importance of combining the two fields of application, that is, integrating human aspects, such as training, engagement, and satisfaction of employees (ergonomics as a whole), in the context of Lean process improvement, using tools such as DMAIC.

In order to meet customer demands and reduce waste, many companies are adapting and transforming their processes, and this also applies to the logistics sector. For customers, expenses related to the storage, movement and control of materials do not add value. Therefore, any reduction in waste in these activities represents a significant gain for the company.

1.1. Goal

Therefore, as an objective, the project aims to propose and implement improvements to the current process of inventory and registration of materials, of a company in the metallurgical sector, addressing the concepts of lean production, continuous improvement and ergonomics, through the application of the DMAIC process.

1.2. Methodology

This work is characterized as an applied research, of a quantitative nature and exploratory objective (NASCIMENTO, 2016). In order to meet the proposed objective, the DMAIC method was followed, integrated with the AMT Method (Macroergonomic Analysis of Work), to propose an improved future process.

The DMAIC cycle is a Six Sigma tool, in which the acronym refers to the following steps: *define, measure, analyze, improve & control*. This tool serves to direct the application of the work in the company, as its phases are structured and can be monitored by the company, which is the main stakeholder in the project. Considering that the focus of the work is human factors, the method of Macroergonomic Analysis of Work (AMT), proposed by Guimarães (1998), was chosen. Figure 1 demonstrates how the applied methodology will work, integrating the AMT methodology with the DMAIC cycle.

Figure 1 - Methodology applied integrating AMT and DMAIC.

Source: The Authors, 2023

2. DEVELOPMENT, RESULTS AND DISCUSSION

To better demonstrate the results, the topics were separated in the same structure presented by the DMAIC methodology.

2.1. Sets

To start the project, a little was understood about the company that is a reference with regard to oil and gas extraction systems and, currently, due to the generation of new types of

energy, the company decided to cover the new niches generated from new technologies, promoting sustainable energies.

When planning a production, an optimization of the resources available from the SAP® system (*System Applications and Products in Data Processing*) is carried out. If there is a discrepancy between the physical materials versus the quantity indicated in the system, it is necessary to carry out a new planning to determine the demands arising from the obstacle of lack of the physical part. Due to this, the accuracy indicator is of great importance within a process, since it is the factor that indicates how well adjusted the physical inventory is in relation to the system and, for this reason, this is the metric used in the project. This indicator is measured according to Equation 1. This indicator is subject to internal and external auditing, which brings greater reliability to the data presented.

$$Accuracy\ (\%)\ = \left(1 - \frac{Theoretical\ value\ - Real\ Value}{Theoretical\ value}\right) x\ 100$$

Equation 1. Formula for calculating the percentage of accuracy.

For the 2022 cycle, the company made three people available in the two shifts to carry out the count. The analysis of the company's historical data (average of 90%) showed that there is a great variability between the accuracy data, since each material has different size, quantities and arrangements on the shelves, which can facilitate or hinder the counting process, since it is done manually by the stockists. Gains will be measured in recovered working hours due to a higher level of accuracy. To better understand the company's process, a SIPOC (*Suppliers, Inputs, Process, Output and Customers*) process map was prepared of the flow of the main process studied (Figure 2).

Figure 2 - SIPOC Matrix

Suppliers	Inputs	Process	Goods	Consumers
Suppliers	**Inputs**	**Process**	**Outputs**	**Customers**
Supplier	Submitted part	Receive the part	Received part	Receiving Area
Receiving Area	Received part	Update Status in SAP	Status of the part updated in the system	Quality Inspection Area
Quality Inspection Area	Updated Part Status in the system	Inspect Parts	Approved part	Quality Inspector
			Failed part	Quality Inspector
Quality Inspector	Approved and disapproved part	Update Status in SAP	Status of the part updated in the system	Approved part - stockist Failed part - Supplier
Stockist	Status of the part updated in the system	Allocate parts to inventory according to MRP	Part allocated in stock according to MRP	Stockist
Stockist	Part allocated in stock according to MRP	Ordering Assembly Assembly Materials	Requested material	Project Manager
Project Manager	Requested material	Find parts in stock	Localized parts	Stockist
Stockist	Localized parts	Separating Parts for Assembly Assembly	Separate set	Stockist
Stockist	Separate set	Update Status in SAP	Status of the part updated in the system	Assembly Manager

Assembly Manager	Status of the part updated in the system	Position on the assembly line	Positioned set	Assembly Line

Source: The authors, 2023.

2.2. Measure

The process was stratified from the result of the last cycle count. Stratification showed that 20% of the requested materials are not located, causing the "lost" hours of work to increase. In this way, it was analyzed which are the main points that are affected by this non-location of the material, without, therefore, there are: incorrect counting (53%), incorrect address (20%), no definition (13%), divergence of consumables (6%), shipping error (5%) and incorrect material (3%). As a result, as the first two (incorrect count and incorrect address) form 73% of the cause, these were defined as the focus of the project. The priority goals were defined by the behavior of these focuses over time, validating the achievement of the global goal proposed by the company (Figure 3).

Figure 3 - Specific goals for each focus

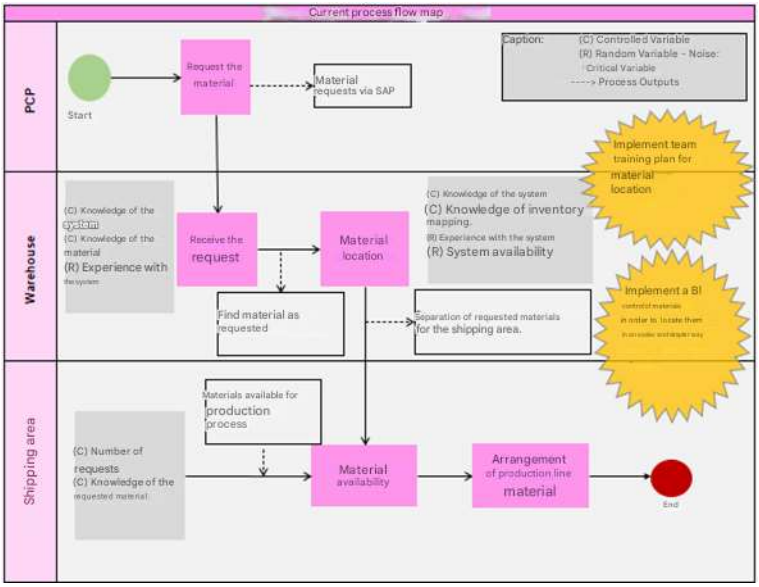
	Stratum	Current	Meta
Meta 1	Incorrect Count	53%	30%
Meta 2	Addressing error	20%	15%
	No Definition	13%	13%
	Consumables divergence	6%	6%
	Shipping error	5%	5%
	Incorrect Material	3%	3%
Total		100%	72%
% of not found		20%	14.50%
% inaccuracy		7%	5%
% accuracy		93%	95%

Source: The Authors, 2023.

2.3. Analyze

To identify which are the points of improvement for each step of the process, a swimlane map was prepared – as shown in Figure 4.

Figure 4 - Current process flow map



Source: The Authors, 2023.

To better understand the causes of the problems, considering the human factors, the survey was carried out using the AMT ergonomics method proposed by Guimarães (998), see Figure 5.

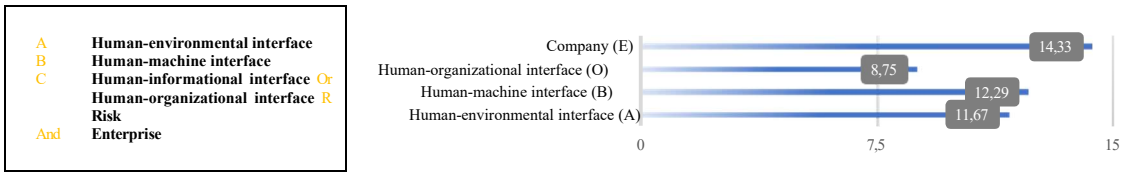
Figure 5 - Application of the AMT tool.

Phase		Description
Phase 0	Project launch and planning of the field survey	As the company does not have an ergonomics committee, the survey took place in the form of an interview with the operators of the stock shed to be analyzed. 6 interviews were carried out on 05/17/2022, among the interviewees there were 5 stockists and 1 logistics manager.
Phase 1	Initial lifting or ergonomic appreciation	For the development of the initial survey, direct observations of users were used. The questions were posed in an open way so that the interviewees could put their observations, according to the suggestion of Guimarães (1998), in the order they found most relevant. From the record of the answers given by each of the interviewees, it was possible to tabulate the answers and order them According to the degree of prioritization (order in which the problem was mentioned), the weights of importance were defined for each item mentioned.
Phase 2	Situation analysis or ergonomic diagnosis	A questionnaire was applied in which employees answered on a scale of agree and disagree, in 15 cm lines, in which the distance represents the employee's level of agreement. From these results, it is possible to analyze which are the main opportunities within FDIs, which have the possibility of affecting the indicator studied and which are the areas where employees are satisfied.

Source: The Authors, 2023.

Within the material inventory process, there are 6 employees and the 6 were interviewed. They were asked through open interviews: "Tell me about your work: what are the positive and negative points and present suggestions for improvements". Afterwards, a questionnaire was applied that presents general points about the workstation in order to assess the satisfaction of employees in relation to the items related to the ABCORE classification (Figure 6), developed according to the constructs proposed by Guimarães (1998). The questionnaire was applied to 5 people, as they participate in the activity directly.

Figure 6 - Meaning of the acronym ABCORE and results.



Source: The Authors, 2023.

For the Ergonomic Demand Items (IDEs) A, B, O, and E studied, none of them presented a result below the average, which is considered a very positive result. For the items of discomfort (R) and content of the work (C), the result is presented in an inverse way – since it presents criteria, such as pressure at work, that the lower the value placed, the better. For the construct of work content, the average satisfaction result was 7.60, which shows a niche opportunity, since it highlights the need of employees to feel satisfied with their work. For the Risk category, questions were used regarding the discomfort of performing the tasks. As the result of this pillar has an average of 5.82, it is instigated to seek solutions to these discomforts in order to prevent future injuries to employees.

After the analysis of the results collected by the AMT, Figure 7 is presented, which summarizes the causes raised.

Figure 7 - Summary of the causes raised.

ABCORE Factor	Ergonomic Demands Item (IDE)
Human-environmental interface (A)	Temperature of your working environment
Work Content (C)	Amount of work you perform (workload)
	Is your work limited?
	Is your job stressful?
	Do you feel psychological pressure from your superiors?
	Is your work creative?
	Is your work dynamic?
	Is your work stimulating?
	Does your job involve responsibility?
	Does your work make you feel valued?
Human-organizational interface (O)	Customer Relationships
	Flexible working hours
	time available to carry out their daily work activities
	clarity in the distribution of daily professional activities (e.g., who separated notes, etc.)
	How your work is planned (goals and activities)
	How the management of customer orders is received (e.g., separation of activities)
	Leadership's way of acting
Discomfort (D)	Mental effort required
	Discomfort or Pain in the Arms
	Discomfort or Pain in the Hands
Causes raised by the interviews	High demand
	Training
	Interruption during counting
	Long counting times

Source: The Authors, 2023.

The causes raised in red will not be addressed at work, as they are part of an organizational culture that needs to be restructured and, in this way, bring a more complex change to be implemented.

To prioritize the causes raised, the Severity, Urgency and Trend (GUT) matrix was used (Figure 8), considering the items scored by the employees in the interviews as a priority, since they are the causes that most bother the employees. In addition, the prioritization criterion was considered to be causes that were above 75 points (in bold).

Figure 8 - GUT matrix.

Classificação	GUT	Causas	Gravidade	Urgência	Tendência
8 º	75	**Falta de dispositivos ergonômicos**	5	5	3
11 º	45	Trabalho repetitivo	3	3	5
6 º	80	**Clareza na distribuição das atividades diárias**	4	5	4
1 º	125	**Planejamento das atividades (metas e objetivos)**	5	5	5
1 º	125	**Gestão no recebimento de pedido do clientes (exemplo: separação das atividades)**	5	5	5
1 º	125	**Forma de agir da liderança**	5	5	5
12 º	36	Temperatura do meio ambiente	3	3	4
6 º	80	**Dificuldades no uso dos softwares e sistemas - falta de treinamento**	5	4	4
10 º	48	Longos tempos de contagem	4	3	4
12 º	36	Falta de fomas de medições automáticas da acuracidade	3	3	4
5 º	100	**Esforço físico**	5	5	4
15 º	24	Trabalho monótono	4	3	2
16 º	18	Trabalho pouco criativo	3	3	2
17 º	12	Trabalho pouco dinâmico	3	2	2
12 º	36	Trabalho pouco estimulante	3	4	3
9 º	60	Trabalho cansativo	5	4	3
1 º	125	**Desconforto e dores no corpo**	5	5	5

Source: The Authors, 2023.

For work planning (goals and activities), management in receiving customer requests (e.g., separation of activities) and the way leadership acts, are more complicated causes and were out of scope, since they involve cultural change within the company and must be a work developed in a more detailed, slow and gradual way. These opportunities pointed out by the employees were communicated to the manager in order to understand the points of dissatisfaction of the employees. It is worth mentioning that this dissatisfaction presented by employees can influence the stratum of counting errors, since this error can occur due to the fact that employees feel pressured by leadership.

To deal with them, it is suggested the implementation of flexible working hours and a planning of the activities performed by employees, including: activity, description, responsibility, average time of performance (to balance the workload among employees) and goals (expectation of the result of that activity).

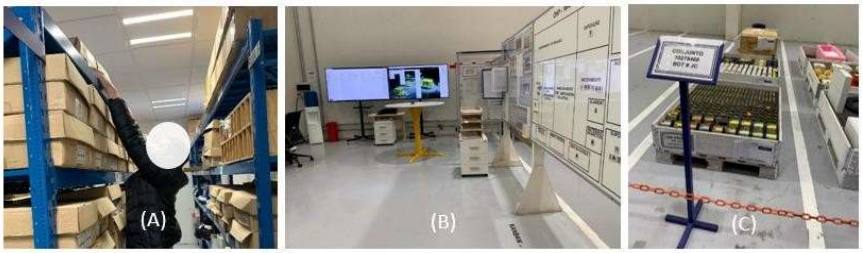
Thus, four main causes are prioritized and defined: Lack of ergonomic devices, Difficulties in using software and systems, Physical exertion, and Discomfort and body pain. To quantify these causes, there was a correlation between the foci and the prioritized causes, and each of them was described (Figure 9), evidencing them (Figure 10).

Figure 9 - Quantification of prioritized causes

Count Incorrect	Error addressing	Prioritized cause	Description of the cause	Evidence
X		Lack of ergonomic devices	Difficulty in performing tasks due to lack of ergonomic devices.	Figure 10 (a)
	X	Difficulties in using software and systems	By not knowing how to handle the system, there is the incorrect addressing of the materials inside SAP® software.	Figure 10 (b)
X		Physical exertion	Materials positioned in hard-to-reach places with few tools or devices to assist in the storage and separation of materials	Figure 10 (a)
X		Discomfort and body aches	Due to the performance of repetitive work at long intervals of time, there is a discomfort and pain generated by this cause.	Figure 10 (c)

Source: The Authors, 2023.

Figure 10 - Detailed evidence.



Source: The Authors, 2023.

By observing the posture that the employee needs to position himself in order to pick up the material (Figure 10 A), there are several opportunities for improvement. In a period of 1 hour, the employees searched an average of twelve times for materials weighing an average of 6 kilograms, on a shelf with its shelf at 2.00 meters high, which will be placed on a cart 0.50 meters from the ground. To reach the 2.00-meter-high shelf, a three-level staircase is used that reduces this height to 1.50 meters in height. The employee must stretch his arms to pick up the material, staying 0.55 meters away from the body. Because they are boxes, the handle is poor, as it does not have a good support for the hands. An analysis was performed using the NIOSH method that resulted in a survey index of 2.53, which fits into a moderate increase in this risk (index is between 1 and 3). It is suggested to use ergonomic devices and position items of smaller quantities, lighter and less frequent of need on the higher shelves.

When analyzing Figure 10 B, it is possible to notice that the place of access to the system does not have any type of work instruction (whether visual or written), close to the computers, therefore, there is no standardized way to guide the use of the *software*, which generates difficulty when executing the program. To register the address, the requesters print a report with the requested materials and pass it on to their supervisor to sign, approving the request. Afterwards, the requester takes the document to the warehouse. The stockist separates and

delivers the material, thereby collects the papers and charges the withdrawal to the SAP® system.

When analyzing Figure 10 C, it is verified that the employees do not have a specific place, such as a bench, to count and separate the materials. The materials are arranged in buckets and pallets on the floor, causing the employee to bend down and get up constantly during the working day – generating physical effort.

2.4. Measure

At this stage, the solutions were identified after a brainstorming of the group together with the company's logistics management. Afterwards, the ideas that best addressed the causes were prioritized in order to mitigate the opportunities found in the project (this stage encompasses Phase 3: proposal of solutions) - for this purpose, Figure 11 was obtained.

The solutions were based on tools available within the company, such as Microsoft 365®, and on tools that are not applied, but are proven solutions – as is the case of the application of RULA and OWAS or NIOSH in cycles, which is recommended since it acts not only reactively, but also preventively. Within this analysis, a Likert scale from 1 to 5 was considered, with 1 being low or bad and 5 being high or excellent.

Figure 11 - Improvement opportunity matrix, proposed solutions and risks.

INCORRECT COUNTING	ADDRESSING ERROR	PRIORITIZED FOCUS	CLASSIFICATION	PROPOSED SOLUTION	BENEFIT	SCOPE	INTERNAL SATISFACTION	OPERATIONALIZATION	PRODUCTIVITY	INVESTMENT	TOTAL	PROBABILITY	IMPACT	RISK	CONTINGENCY PLAN
X		Lack of ergonomic devices	7	Develop ergonomic devices (such as carts, ladders, and support tools) for the inventory process.	4,7	4,3	4,7	3,0	4,7	5,0	**16,4**	75%	8	High	Request budget adjustment and present the financial return
	X	Difficulties in using software and systems	8	Conduct training with employees in the SAP® tool.	4,3	4,7	4,3	3,6	3,0	4,3	**15,6**	-	-	'	-
			5	Implement an integrated, auto-flow requisition system from the powerautomate integration and SAP.®	5,0	4,3	4,7	3,6	4,7	4,3	**18,0**	5%	9	Low	Use a warehouse to place data intermediately with systems
			2	Development of a standard procedure for using the software, so that the employee can easily and quickly verify how the address is carried out.	4,7	5,0	3,6	5,0	4,7	3,0	**20,0**	30%	7	Medium	Seek to train and encourage employees to always follow the planned process
			3	Develop a dashboard in powerbi with the location of the items in the layout of the logistics shed.	4,7	4,5	4,3	4,7	4,5	3,0	**19,7**	40%	8	Low	Publicize the change and constantly make employees aware of the importance of their adherence to the new method
X		Physical Exertion	1	Provide a bench or table so that the employee can separate and count the materials.	4,5	3,6	5,0	5,0	5,0	2,1	**21,0**	75%	9	High	Revisit the layout to reduce "dead" spaces

X		Discomfort and body aches	6	Application of ergonomic appreciation tools, such as RULA and OWAS or NIOSH, with application cycles every 3 months.	4,7	5,0	4,7	3,0	4,5	4,3	**17,6**	45%	9	Medium	Show successful cases with the application of the tool to raise awareness and gain the support of senior management
			4	Implementation of breaks, rotation of activities to reduce repetition of the same activity and position in long intervals of time.	4,3	5,0	4,3	4,7	4,3	3,0	**19,6**	60%	8	Medium	Make a good operation plan, leaving extra time for scheduled breaks

Source: The Authors, 2023.

For the investment, both the value of the application of the solution and the time spent for the development of the proposed solution were considered. Only the training solution was disregarded, as it would require several rounds of training with employees, the hiring of a specialist to carry out the training. For the definition of tests and validation of the proposals (this being phase 4 of the AMT method), a 5W2H matrix was developed for the test plan – as shown in Figure 12 and the costs involved are described in time.

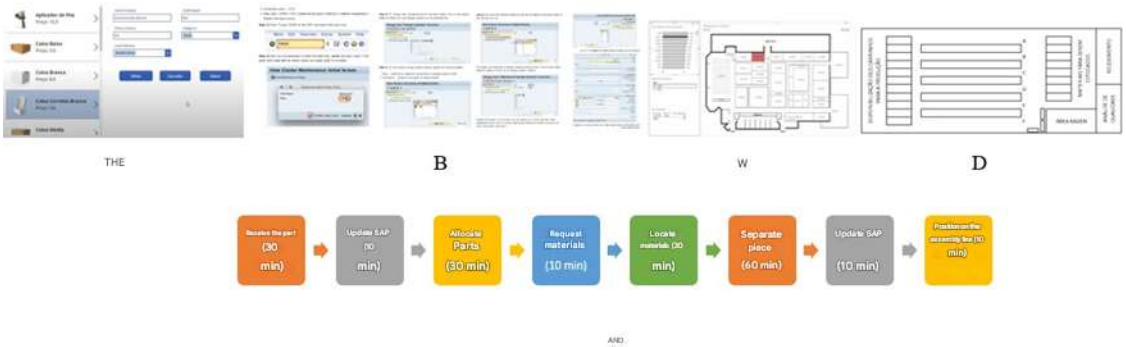
Figure 12 - 5W2H of the tests of the proposed solutions and tests

Incorrect counting	Addressing error	Fundamental cause	Solution to be implemented for testing	5W2H							Status	Evidence from the Tests
				What (Activity)	Who	When	Why (Por Quê)	Where	How	How Much (Quanto Custa)		
X		Lack of ergonomic devices	Develop ergonomic devices (such as carts, ladders, and support tools) for the inventory process.	Analyze the activity carried out, develop prototypes of ergonomic devices	(EHS Analyst)	02/09/2022	To adjust devices to employee needs	Logistics shed	Prototyping for solution validation	400 hours	In progress	In progress
	X	Difficulties in using software and systems	Implement an integrated and auto-flow requisition system from the integration of powerautomate and SAP.®	Conduct a pilot project with employees to adapt the system to be closer to the needs	(Logistics Assistant)	10/09/2022	To adjust the new process according to needs and with proper accessibility to the employees	PowerApps	Creating an app in powerapps	100 hours	Done	Figure 13 A
			Development of a standard procedure for using the software, so that the employee can easily and quickly verify how the address is carried out.	Meetings with employees	(Logistics Intern)	02/09/2022	To cover employee difficulties within standard procedure	Logistics shed	Carry out a draft of the standard procedure with employees, checking the biggest difficulties found in everyday life	150 hours	Done	Figure 13 B **Error! Reference source not found.**
			Develop a dashboard in Power BI with the location of the items in the layout of the logistics shed.	Conduct a pilot project with employees to adapt the system to be closer to the needs	(Logistics Assistant)	15/09/2022	To adjust the new process according to needs and with proper accessibility to the employees	Power BI	Creating a dashboard to locate the parts on the map in Power BI	100 hours	Done	Figure 13 C
X		Physical Exertion	Provide a bench or table so that the employee can separate and count the materials.	Layout review	(factory project analyst)	10/09/2022	To check the availability of physical space in the shed	Logistics shed	Revision of the layout in order to verify the possibility of including benches for employees	50 hours	Done	Figure 13 D
X		Discomfort and body aches	Application of ergonomic appreciation tools, such as RULA and OWAS or NIOSH, with cycles every 3 months.	Research and benchmarking	(EHS Analyst)	12/09/2022	To see the advantages of applying the tools	Logistics shed	Analysis of successful cases with the application of the tools and definition of the Tool used	400 Hours	In progress	In progress
			Implementation of breaks, rotation of activities to reduce repetition of the same activity and position in long intervals of time.	Chrono analysis of activities	(PCP Analyst)	08/09/2022	To verify the possibility of inserting breaks without impact on process activities productive	Logistics shed	Analysis of the impact of breaks throughout the day on the inventory process	150 hours	Done	Figure 13 E

Source: The Authors, 2023.

For the details of the tests, the 5W2H matrix was presented. Thus, there are two actions in which the tests are more elaborate and are still in progress and, therefore, the effects of these actions will not be evaluated.

Figure 13 - Illustrative figure of the application for registration of materials and inventory control developed.



Source: The Authors, 2023.

In order to respect the company's privacy issue, merely figurative images were placed. The flow worked satisfactorily and was well accepted by the employees, so the solution will be implemented. Figure 13 C represents the inventory map in order to facilitate the location of the materials. The employee looks for the *part number number*, checks where it is located and the available quantity of the material. With the layout presented in Figure 13 D, it is feasible to make tables and countertops available so that employees can separate and count the pieces. Finally, from the chrono-analysis carried out (Figure 13 E), which totaled 240 minutes for the complete process, it was possible to verify that there is the possibility of inserting 2 rounds of 15 minutes of stretching and changing activity within the process, without impacting the operational process.

With the test round completed, a plan was made to implement the solutions in order to carry out this implementation gradually and incisively. The solution for implementing breaks was met, as the company has already reduced demand in order to make more time available for the employee to carry out activity changes and breaks. Regarding the other activities, these present a very positive scenario, with the risks well mapped and mitigated. To verify the results of the actions, Figure 14 was elaborated.

Figure 14 - Verification of the results of the implemented solutions.

Incorrect counting	Error	Fundamental cause	Solution deployed	Implementation result	Status
X		Lack of devices Ergonomic	Develop ergonomic devices (such as carts, ladders, and support tools) for the inventory process.	-	Not started
	X	Difficulties in using software and systems	Implement an integrated and automatic flow requisition system to from the integration of powerautomate and SAP.®	Figure 13 A	Implemented
			Development of a standard procedure for using the software, so that the employee can easily and quickly verify how Realization of the address.	Figure 13 B	Implemented
			Develop a dashboard in Power BI with the location of the items in the layout of the logistics shed.	**Error! Reference source not found.** 13 C	Implemented
X		Physical Exertion	Provide a bench or table so that the employee can make the separation and counting of materials.	It is in the process of buying the countertops.	In progress

X		Discomfort and body aches	Application of ergonomic appreciation tools, such as RULA and OWAS or NIOSH, with application cycles every 3 months.	-	Not Started
			Implementation of breaks, rotation of activities to reduce repetition of the same activity and position in long intervals of time.	A reduction in daily demand was carried out, in order to make more time available for the employee to take breaks. The results will be demonstrated qualitatively in the long term.	In progress

Source: The Authors, 2023.

As the actions with the applications and standard procedure implemented were the validation of the proposed pilot and refinement of the system according to the feedback of the employees, the results of the actions remain the same as presented in the testing phase.

2.5. Control

For the final stage of the application, it was verified whether the defined goals were achieved (Figure 15).

Figure 15 - Description of the achievement of the goals.

	Stratum	Initial	Current	Goal
Goal 1	Incorrect Count	53%	33%	30%
Goal 2	Addressing error	20%	16%	15%
	No Definition	13%	13%	13%
	Consumables Divergence	6%	6%	6%
	Shipping error	5%	5%	5%
	Incorrect Material	3%	3%	3%
Total		100%	76%	72%
% of not located		20%	15,20%	14,50%
% of inaccuracy		7%	5,32%	5%
% accuracy (global target)		**93%**	**94,68%**	**95%**

Source: The Authors, 2023.

The specific targets were achieved and the result is satisfactory, since they are only 0.32% below the global target. With the reduction in the percentages of non-located materials and the increase in the reliability of inventories, it is possible to estimate that there was a gain of 2,400 productive hours per year – considering the gain of 2 hours of productivity per day, for 20 working days, for the 5 stockists. Despite the relatively low value of financial return, it is worth mentioning that there was an improvement in the quality of life at work of employees, which cannot be measured in a monetary way. To conclude the application of the DMAIC cycle, there is a definition of ways to keep the process sustainable, so key actions were defined so that this result obtained is maintained (Figure 16).

Figure 16 - List of variables and forms of monitoring.

VARIABLE	FORM OF MONITORING
Accuracy	Annual reports for follow-up
Failure to locate the materials	Weekly reports of time spent with the Location of the materials and the reason
Work Standards	The logistics intern must check if there is a use of the work instructions and the updating of these instructions
Tools developed	The logistics intern must check if there are opportunities in the use of the tools, as well as such as updating these.
Ergonomics	The EHS analyst must perform in a cyclical manner Ergonomic appreciation

Source: The Authors, 2023.

For the team's recommendations, there is the final phase of the application of the AMT method, Phase 5: ergonomic detailing. From the study carried out, it was possible to identify opportunities for improvement within the analyzed process.

By analyzing the company's inventory process for the development of this activity, it was identified that it is a highly repetitive process that requires many movements in uncomfortable positions. It is suggested to establish more relaxed breaks, encouraging employee iteration and relaxation to evacuate the stress, tension, and monotony of work.

In addition, an important point that employees made clear both in the interviews and in the questionnaire is dissatisfaction with leadership. Thus, it is suggested to conduct a general satisfaction survey and appreciation of the organizational culture with employees, in order to identify the main points of opportunity for the company. Finally, to promote motivation and encouragement to employees, it is recommended to implement bonuses and recognition programs based on proposed improvements and the work done. In addition, it is suggested to promote leadership meetings more closely with employees, both for feedback and to understand the worker's growth expectations. It is suggested to expand this study to other areas of the company in order to make a complete assessment of the company's scenario.

3. FINAL CONSIDERATIONS

In order to improve the process of inventory and registration of materials in a company in the metallurgical sector, from the involvement of employees, the application of the DMAIC cycle was carried out together with the AMT method. The final product of this project consists of an improved process, which takes into account the company's reality, human factors and lean production.

Through interviews with employees, dissatisfaction with management and organizational climate was found. As this problem is more complex, feedback was reported to the company and the topic was not addressed in the proposed improvement cycle. The main opportunities identified were: temperature of the work environment, problems related to the content of the work (such as limitations, workload, stress and lack of dynamism and stimulation), little time available to perform activities, poor clarity of these activities, poor distribution of responsibilities, high mental and physical effort required, discomfort in the upper limbs, lack of training and ergonomic devices and long counting times (task continuous for long periods of time).

Among these main opportunities, the causes that would receive actions in this cycle of continuous improvement were prioritized. This prioritization occurred through the GUT matrix and the improvement opportunity matrix. Based on the priority causes (upper limb pain, training, physical exertion and lack of ergonomic devices), a detailed test, action and control plan was developed in order to structure long-term sustainable solutions and mitigate these points of dissatisfaction.

In order to maintain the results, the development and implementation of new processes (registration by powerApps and verification in Power BI) was carried out and a standard operating procedure was developed for the registration of the addressing of the materials. As the development and implementation process involved all employees who have an interface with the processes, the training process was carried out in a brief expository meeting that showed the final version and resumed in a summarized way the functioning of the processes.

As the main recommendation, it is suggested the adoption of ergonomic assessment tools and the periodic performance of these assessments. In relation to the goal established by the company, which was to achieve an accuracy of 95%, this goal was practically achieved (being only 0.34 percentage points below).

Finally, it is concluded that considering the human aspect during the improvement cycle can lead to positive results for the company. Therefore, projects of this nature contribute to recovering the importance of considering human factors in improvement projects and should be promoted in the field of engineering.

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