The effects of integrated Lean Six Sigma methodology with ergonomics principles in the garment industry

DOI: 10.35530/IT.076.01.202461

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ABSTRACT – REZUMAT

The effects of integrated Lean Six Sigma methodology with ergonomics principles in the garment industry

The present paper introduces an integrated model that combines the use of ergonomics with Lean Six Sigma (LSS) methodology based on the DMAIC (Define, Measure, Analyse, Improve, and Control) approach. In each DMAIC phase, an additional ergonomic perspective was integrated to improve the process both from the efficiency and ergonomic side. The present study was carried out in a textile industry specialized in the manufacture of articles for technical use. The study's aims are the following: achieving continuous improvement by eliminating waste, decreasing activities that are Non-Value Added, and preserving workers' health while focusing on external and internal productivity. It began with a defined stage intended to increase Value Added (VA) activities by reducing Non Value Added (NVA) through waste removal, to around 48.5%, increasing the cycle time to 4.6 %. The finding has led to the conclusion that an integrative approach has ultimately secured the workers' lives and boosted their operational performance.

Keywords: *Lean Six Sigma, ergonomics, clothing industry*

Efectele metodologiei Lean Six Sigma integrate în principiile de ergonomie din industria de îmbrăcăminte

Lucrarea de față introduce un model integrat care combină utilizarea ergonomiei cu metodologia Lean Six Sigma (LSS) bazată pe abordarea DMAIC (Definire, Măsurare, Analiză, Îmbunătățire și Control). În fiecare fază DMAIC, a fost integrată o perspectivă ergonomică suplimentară pentru a îmbunătăți procesul atât din punct de vedere al eficienței, cât și al ergonomiei. Acest studiu a fost realizat în industria textilă specializată în fabricarea articolelor de uz tehnic. Obiectivele studiului sunt următoarele: realizarea îmbunătățirii continue prin eliminarea deșeurilor, scăderea activităților care sunt fără valoarea adăugată și păstrarea sănătății lucrătorilor, concentrându-se în același timp pe productivitatea externă și internă. S-a început cu o etapă de definire menită să crească activitățile cu valoare adăugată (VA) prin reducerea celor fără valoare adăugată (NVA) prin eliminarea deșeurilor, la aproximativ 48,5%, mărind timpul ciclului la 4,6%. Analiza a condus la concluzia că o abordare integrativă a îmbunătățit în cele din urmă viața lucrătorilor și le-a sporit performanța operațională.

Cuvinte-cheie*: Lean Six Sigma, ergonomie, industria de îmbrăcăminte*

INTRODUCTION

Lean Management and Six Sigma philosophies are to be considered as the most promising initiatives in the continuous improvement of organizations [1, 2]. Indeed, this method is widely used by firms throughout the world in various industrial fields that include manufacturing [3–7], services [8, 9], commercial [10], health care [11, 12] and textile [13].

Ergonomics (or the study of human factors) is the scientific discipline that aims at a fundamental understanding of the interactions between human beings and the other components of the system. Ergonomics considers both the physical and psychological human aspects and is interested in looking for solutions in both the technical and organisational domains [14]. Several techniques have been used for the systematic and comprehensive assessment of a workstation [15].

The implementation of Lean Six Sigma (LSS) tools was beneficial. Yet, it can cause ergonomics problems, but with promising modifications. This failure occurs because several organizations focus only on implementing Lean Six Sigma (LSS) tools and do not consider the workers' security measures [16]. While trying to maximize productivity and improve working conditions, the interventions suggested by this methodology can compromise workers' health by reducing the high level of physiological and psychological stress [17–19]. The employment of ergonomics simultaneously with the LSS implementation process is consensual [20–22] and can easily miss the needs of the human factor in the production process. In addition, ergonomics must be integrated simultaneously with Lean to evaluate the effect of Lean improvements, for example, musculoskeletal disorder (MSD) risk factors associated with the job [23, 24].

To reach this goal, the current study presents the results of integrating ergonomics with Lean Six Sigma (LSS) implementation in the garment industry.

The remnant of this paper is as follows: the 2nd section explores the methods included in the different steps involved in this study. The 3rd section sets out the result and discussion which examines the case study and documents the results obtained from applications in the clothing industry. Then the 4th section includes a conclusion with future research.

METHODOLOGY

Our methodology was designed to help integrate the ergonomics and LSS implementation based on the DMAIC (Define, Measure, Analyse, Improve, and Control) approach. The DMAIC cycle was used because it is a standard method with clear consecutive phases: problem-solving and process continuous improvement [30]. Figure 1 shows the corresponding methodology.

In each DMAIC phase, an additional ergonomic perspective was integrated to improve the process both from efficiency and ergonomics as level follows:

• ***DEFINE PHASE***

In the define phase, we defined the objectives of the project and the current situation of the organization. In addition, Lean Six Sigma (LSS) and ergonomics metrics are selected with the relevant tools.

LSS and ergonomics are key indicators that would help standardize the identified measurements.

• ***MEASURE PHASE***

In the measure stage, data on measurable LSS and ergonomics indicators are collected to evaluate the status of performance metrics at the beginning of the improvement process.

• ***ANALYSE PHASE***

The analysis phase examines the collected data in order to generate a prioritized list of sources of variation. Using the result of the step "Measure", it's becoming possible to determine the root causes of variations and recognize the major problems of productivity and working conditions, revealed in the Define stage.

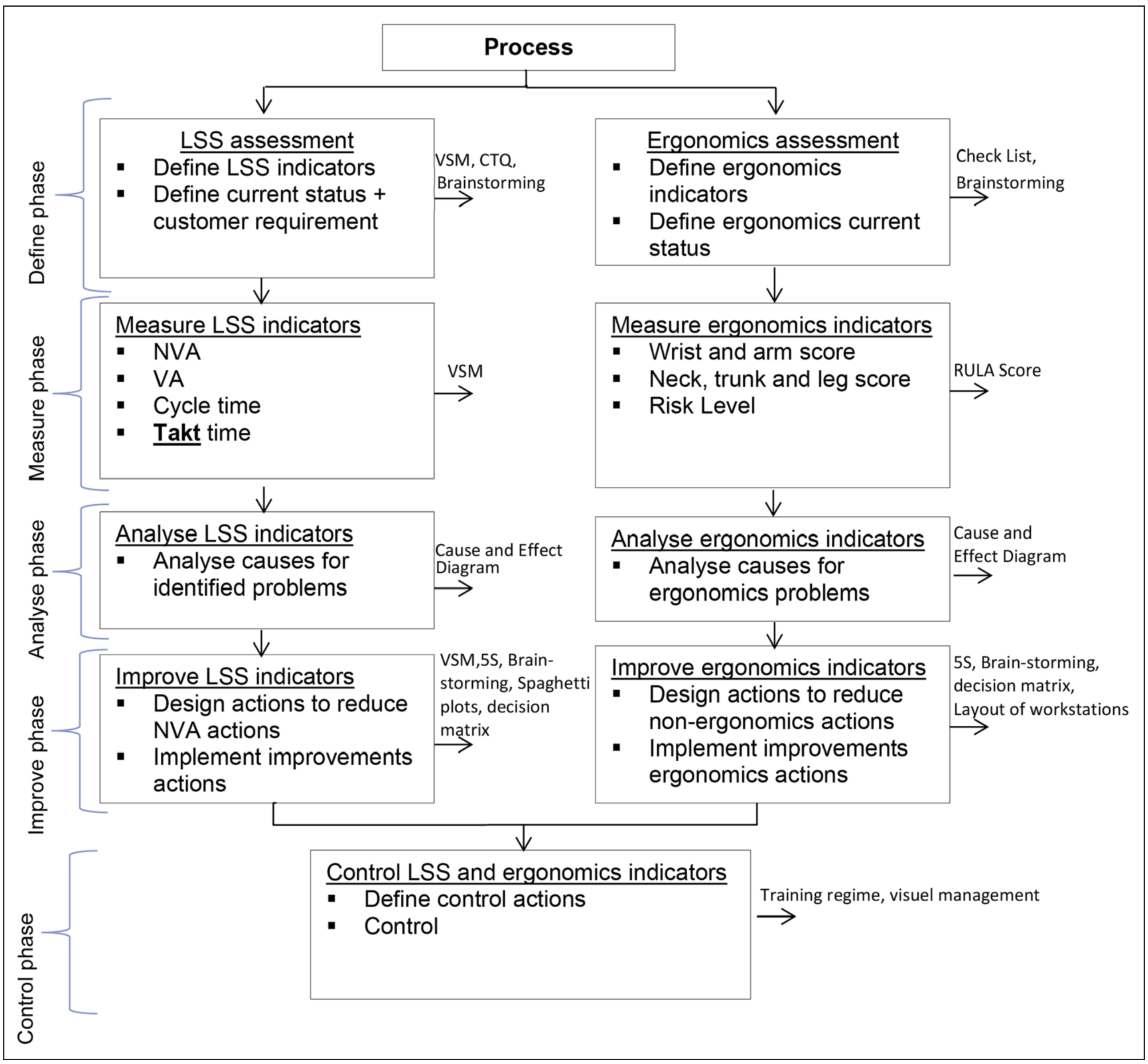

Fig. 1. Research methodology

• ***IMPROVE PHASE***

In the improvement phase, we proposed and implemented some improvement measures to solve the LSS problems and improve the working conditions. Thus, the implementation of Lean Six Sigma (LSS) and ergonomics improvements would ensure the quality of organizational performance taking into account the safety of workers. Consequently, better results are realized, because the well-being of workers is significantly reflected on the efficiency level by reducing non-value-added activities, and increasing the productivity of the organization.

LSS tools such as Value Stream Mapping (VSM), the five S (5S): Sort, Set in order, Shine; Standardize, Systemize, kaizen, brainstorming, cause and effect diagrams are also used in studies of this type. Regarding ergonomic risk assessment methods, several methods were applied in the studies analysed, one of them is RULA. This method has a positive impact on process efficiency and at the same time it allows for reducing the risk level and decreasing the discomfort and fatigue that workers went through [25].

• ***CONTROL PHASE***

The main purpose of this methodology is to improve process performance and working conditions and have the results that are obtained be sustained in the long run. The standardisation of the optimal solutions has been fully integrated into the training regime and the process documentation, and the information related to company performance was shared with its employees. A continued monitoring process and training are required.

CASE STUDY

The present study was carried out in the textile industry specialising in the manufacturing of articles for technical use. The objectives of the work are:

– reducing waste,
– increasing productivity and
– protecting workers and focus on external and internal productivity by integrating LSS and Ergonomics.

Given the complexity of the sewing process of technical products, there were higher demands for the human workforce. The success of this study requires leadership support, employee involvement, and employers' willingness to change and adapt.

• ***DEFINE PHASE***

This phase consists of defining the problem and the customer requirements. The objective is to optimize the process by reducing NVA (Non-Value Added) and cycle time by improving the working conditions. The Critical to Quality (CTQ) essential elements are determined (figure 2).

• ***MEASURE PHASE***

In this step, we will collect data on measurable indicators of production processes and ergonomics perspectives. As referred before, this will evaluate both ergonomic conditions and productivity parameters.

Productivity indicators

The activated VSM provides all details related to the company process as explained in figure 3. The outcomes of Cycle time, Lead time, VA and NAV are presented in the table.

In the current state, the data observed are collected through the VSM. The main indicators observed on the map are:

– Takt time = 5.82 min
– Lead time = 39.41 days + 19.92 minutes = 39.45 days
– Value Added time = 19.92 min
– Non-Added Value time = 39.41 days.

Observing the mapping of the current state we noticed that the sub-assembly process time is greater than the takt time (figure 4), in this situation the production process generates a bottleneck problem, so it becomes necessary to intervene to adapt the rhythm takt time production.

After a close observation, we concluded that the priority problems regarding the previous waste definition are waiting time, transportation, over-processing, motion and excessive inventory.

Transportation and unnecessary motion are the significant types of waste detected in our case study. Even, according to Shigeo Shingo in Peter & Taylor "Excessive movement of people, information or goods resulting in wasted time, effort and cost" [36]. In addition, unnecessary motion can cause twisting, lifting, reaching and walking. Therefore, this may lead to health problems and could endanger the safety of workers.

These types of waste can be reduced by implementing ergonomics perspectives. Once the wastes are eliminated, productivity and ergonomics conditions can be improved simultaneously.

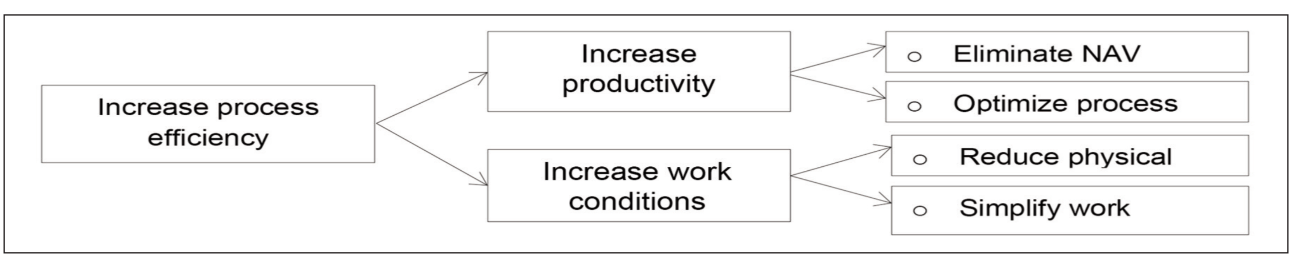

Fig. 2. The Critical to Quality (CTQ)

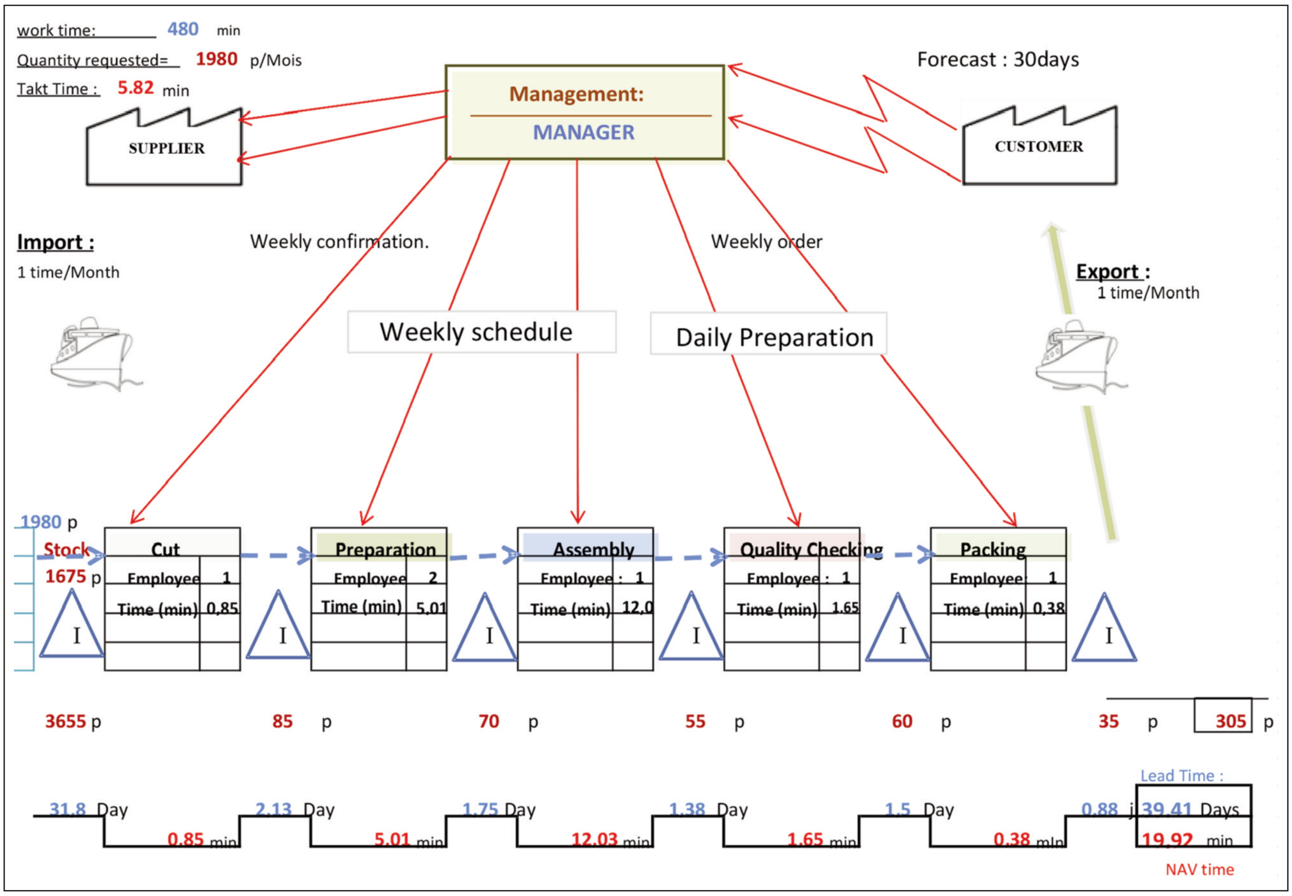

Fig. 3. Activated VSM

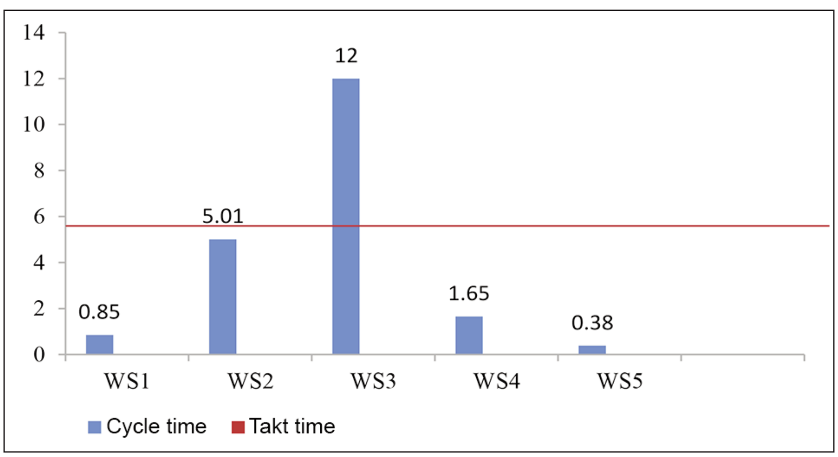

Fig. 4. Cycle times vs. takt time

risk levels of occupational tasks obtained after analysing the posture.

Since the RULA score of WS3 is in the medium risk zone, the working posture needs an immediate investigation. Training for proper sitting as well as standing posture is essential to reduce work-related musculoskeletal disorders (WMSDs) and improve the health condition of workers.

• ***ANALYZE PHASE***

The analysis phase examines the collected data to come up with a prioritized list of sources of variation [28] to identify the root causes of these sources and analyse the problems of variation process inefficiency, by using the result of the "Measure" step. At this stage, the causes of non-value-added activities were determined.

Analysis of different types of process waste

In this step, a real vision of the progress and deviations of the processes is carried out to analyse the flow and to determine through an in-depth study, the different types of the most repetitive waste. Also, possible root causes of problems are identified (figure 5). The causes of Ergonomics risk in the identified workplace are also determined (figure 6).

Work and ergonomic conditions indicators

The three main risks that workers may face are related to musculoskeletal disorders: (WRMSDs) high force, awkward posture, and excessive repetition [37].

To conclude this research, data have been collected through a rapid upper limb assessment (RULA) worksheet. The different postures of workers have been closely observed from the viewpoint of RULA. This observation has been assessed by the RULA score. Also, the various scores have been compiled according to the RULA worksheet to get the RULA grand score. Table 1 presents the different categories of the

Table 1

RULA SCORE						
No.	Part of body	Work Station				
		WS1	WS2	WS3	WS4	WS5
Body Part A						
1	Upper Arm	2	2	1	1	2
2	Lower Arm	2	2	3	1	2
3	Wrist	2	2	4	1	2
4	Wrist twist	1	1	1	1	1
	Score A	3	3	4	1	3
5	Muscle use score	1	1	1	1	1
6	Force/load score	0	0	0	0	0
	Wrist and arm score	4	4	5	2	4
Body Part B						
1	Neck	2	2	3	1	2
2	Trunk	1	3	4	1	3
3	Legs	1	1	1	1	1
	Score B	2	4	5	1	4
4	Muscle use score	1	1	1	1	1
5	Force/load score	0	0	0	0	0
	Neck, trunk and leg score	3	5	6	2	5
	Final Score	3	5	7	2	5
	Level Risk	Low-risk Change may be needed	Medium risk Further investigation, Change soon	High Risk Investigate posture and change needed immediate	Low-risk Change may be needed	Medium risk Further investigation, Change soon

• ***IMPROVE PHASE***

Improve phase of the project has begun with brainstorming to ensure the success of the research and the choice of appropriate improvements to reduce NAV and resolve the problems that were identified in the previous phase.

The development of the action plan necessitates the employment of 10 actions, the Lean Six Sigma project team decided to classify the actions according to their importance. A selection graph allows you to quickly and simply identify the difficulty of implementing an action in comparison to the impact of the expected result.

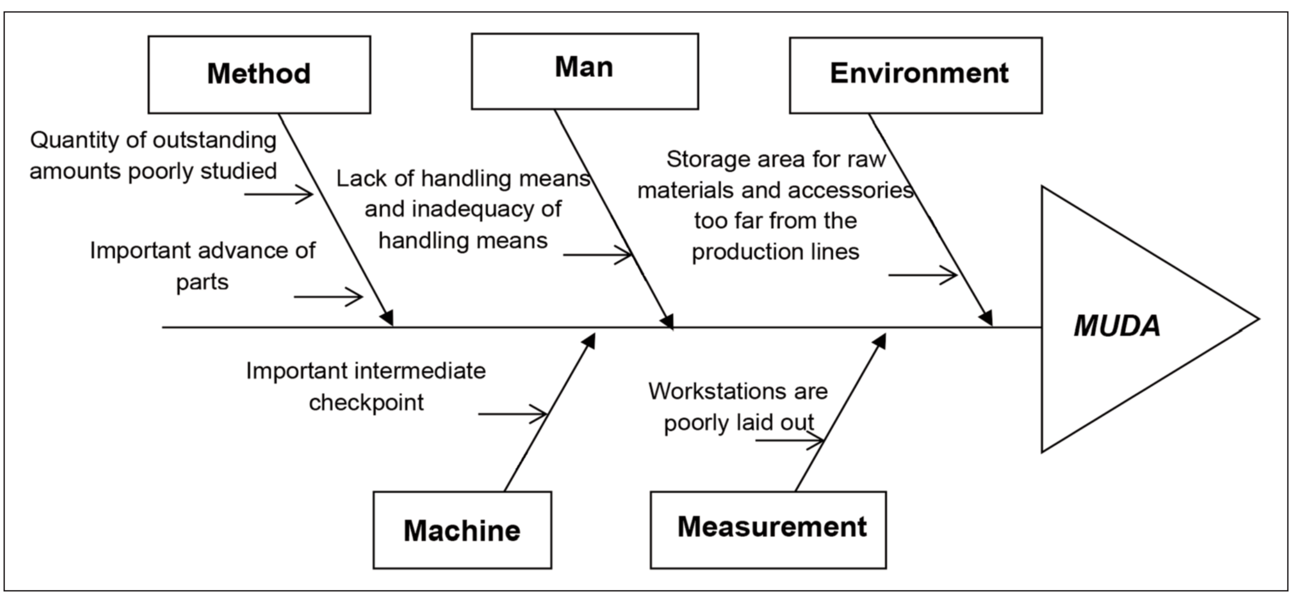

Fig. 5. Cause-effect diagram of MUDA

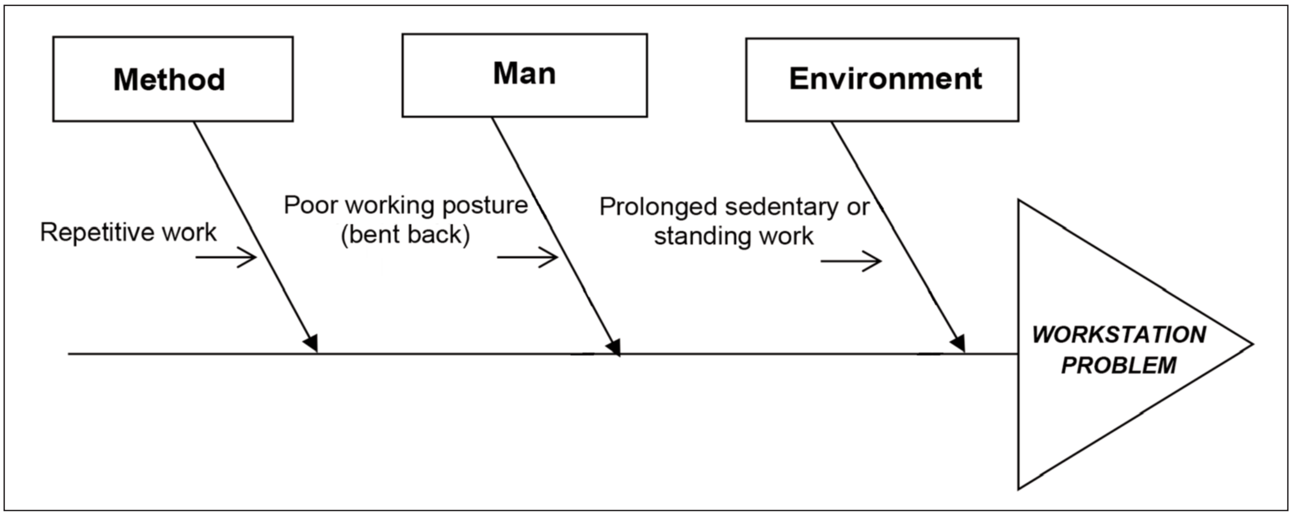

Fig. 6. Cause-effect diagram of work-station problem

Table 2 presents the decision-making matrix for the actions implemented with the following indications:

- The green box presents the actions that will be carried out;
- The red box presents the actions that will not be carried out; and
- The yellow box presents the actions that will be discussed.

Therefore, we will select the predefined actions in the action plan using the decision matrix presented in table 2.

Thus, we have developed an action plan which summarizes the actions implemented in order to reduce or eliminate the different types of Muda that have been encountered. The proposed corrective solutions are presented in table 3.

Table 2

DECISION MATRIX			
Strong	*Review the production schedule	*Minimize the quantity per batch launched	*Modify the supply system
Average	*Modify layouts	*Eliminate intermediate check *Establish an FMEA method	*Change the handling equipment *Study and arrange key workstations
Low	*Establish the follow-up sheet	*Minimize the transport distance by implementing of storage area in the production chain	*Install the machine with a table frame
Implementation difficulty / Impact	Low	Average	Strong

Table 3

PROPOSED CORRECTIVE SOLUTIONS	
Problem	**Corrective Solutions**
Motion	Minimize the transport distance by implementing of storage area in the production chain
Unnecessary inventory	Minimize the quantity per batch launched
Over-processing	Change the handling equipment Study and arrange key workstations
Unnecessary gestures	Change the handling equipment

Table 4

THE DISTANCE BEFORE AND AFTER IMPROVEMENTS	
Parameter	**Value**
Distance (m): before	255
Distance (m): after	123
Gain (m)	132
	51%

Table 5

THE RESULTS BEFORE AND AFTER IMPROVEMENTS			
Parameter	**Before improvements**	**After improvements**	**Gain**
Cycle Time	19.92 mn	19 mn	4,6 %
NAV	39.41 days	20,3 days	48,5 %
Distance	255 m	123 m	51 %

The proposed advancements were implemented on the ground to improve the stability of production processes to the extent of eliminating all types of waste such as unnecessary transport, unnecessary gestures, the excessive stock to stabilize the workstations henceforth, improving the performance of production processes from productivity and ergonomics point of view.

The current facility was improved. When setting up a new facility and applying 5S construction sites in the storage area, the distance travelled to the import/export area and the raw materials store is reduced. We achieved a 51% distance gain in manufacturing processes. The distance gains are presented in table 4. In addition, we have improved the layout of the work area. This eliminates handling tasks that require leaning posture or torsion.

The following table shows significant improvements after implementing the Lean Six Sigma-ergonomics process methodology.

• ***CONTROL PHASE***

The main objective of the Lean Six Sigma methodology is not only to improve process performance but also to achieve greater results in the long term [29]. The improvements that have been made were fully integrated into the training curriculum and process documentation. Information about the company's performance was shared with its employees. A regular audit of the settings was carried out. Once the project is completed, visual management, total productive maintenance and FMEA processes should be implemented to provide a visual aid to control the corresponding key input and output variables and ensure that the team can't go back to old habits.

CONCLUSION

The integration of ergonomics in continuous improvement activities gives the potential to obtain substantial gains in productivity and improve the working conditions of workers at the same time.

This study presents a model regarding the integration of ergonomics and LSS based on the DMAIC cycle. Indeed, in each phase of the DMAIC method, ergonomic tools and methodologies have introduced an additional ergonomic perspective.

The Present study was conducted in the textile industry specialising in the manufacturing of articles for technical use.

It began with a defined stage intended to increase VA activities by reducing NVA through waste removal, to around 48.5%, increasing the cycle time to 4.6 %. This was done by improving Ergo conditions by reducing workers' fatigue and discomfort.

The key finding of this work shows that the company needs to improve its ergonomics conditions and Lean Six by communicating and stressing the importance of the integration of those methods. Hence, the function of every clothing SME is to focus on these parameters.

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