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LEAN THINKING AND HUMAN FACTORS: A PROPOSED MODEL AND APPLICATION IN A HOSPITAL

Cristoffer Rodrigues Poncini[1]*

Camilla Buttura Chrusciak [2]

Rosimeire Sedrez Bitencourt [3]

Osiris Canciglieri Junior[4]

Abstract

The application of Lean can change the way people work and, when Ergonomics/Human Factors is not properly observed, it can have negative impacts on both the human well-being of workers and the work system as a whole. Thus, this article aims to present a proposal for integrating a form of application of Lean with Ergonomics/Human Factors, from a macroergonomic perspective, specifically through a model that integrates the DMAIC method with AMT. To this end, it was carried out as an applied research with an exploratory objective. This research followed 3 stages: i) Literature review; ii) Integration of the DMAIC and AMT Methods; and iii) Experimental case following the proposed structure. The model developed included the use of Lean, through DMAIC, and Ergonomics, through AMT. In the end, the proposed method was applied in a university hospital in the cleaning sector of the surgical center, with gains in several aspects. It is recommended that studies and interventions involving both approaches continue in order to improve efficiency and effectiveness in service organizations, as was the case in the health system where the proposed model was applied.

Keywords: Lean Thinking; Human Factors; DMAIC; AMT.

1. INTRODUCTION

Production Engineering is an area that works to improve processes, bringing greater efficiency to the system and lower costs, and can contribute to the health area. According to the definition of ABEPRO (Brazilian Association of Production Engineering) "Production Engineering is responsible for the design, implementation, operation, improvement and maintenance of integrated production systems of goods and services, involving men, materials, technology, information and energy". The tools used for process improvement are distributed in the various areas of its competence, such as the management of financial, human and material

[1]Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS.*cristoffer0087@gmail.com.
[2]Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS.
[3]Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS.
[4]Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS.

resources, as well as in the association of management techniques, engineering knowledge and fundamentals of economics (BATALHA, 2008).

Among the various tools, philosophies, and improvement methodologies, *Lean* stands out as a philosophy that can be applied in several areas with the aim of reducing waste and improving system efficiency. *Lean* Manufacturing grew out of the Toyota Production System (TPS), also known as *Just-in-time* (JIT), and was created by Taiichi Ohno in 1945, who states that the basis of TPS is absolute elimination of waste and *Just-in-time* means that, in a flow process, the correct parts needed for assembly reach the assembly line when they are needed and only in the quantity needed. Based on this philosophy, Womack and Jones (1996) deepened their knowledge of the *Lean* philosophy and describe *Lean Thinking* as a process management strategy in industrial and non-industrial areas, being a universal form of systems improvement.

Lean addresses several tools for analysis and process improvement. One of the tools used within this philosophy, which aims to improve the process through steps and solve problems arranged in a cyclical and continuous way, is DMAIC (*Define-Measure-Analyse-Improve-Control*). According to Garbuio (2010), DMAIC has become widely adopted within *Lean Six Sigma* projects because it is a method that uses simplified processes with the ability to produce high-quality improvements.

According to Womack and Jones (1996), "*Lean* changes the way people work, but not always in the way we imagine, and workers may find work much more stimulating, but at the same time find their tasks more stressful". This is because the *Lean* philosophy does not fully contemplate the vision of Ergonomics/Human Factors (EFH) applied to the workers involved in the process.

According to Iida (1997), the state of prolonged stress starts to influence work performance, reducing productivity and quality, and can also increase the risks of accidents, absenteeism and worker turnover. In this context, the Human Factors that incorporate the environment, workplace, work organization and the content of the work, bring a global view of the process and the individual in order to optimize the work system as a whole (GUIMARÃES, 2002).

Ergonomics is the science that studies such factors (the Human Factors) and, according to the IEA (*International Ergonomics Association*) (2000), it is the scientific discipline related to the understanding of the interactions between humans and other elements of a system, thus contributing to the project of evaluating work, tasks, products, environment, aiming to make them compatible with the skills, needs and limitations of the human being. Ergonomics,

according to ABERGO (2019), has 3 domains of specialization, namely: physical, cognitive, and organizational. Although these domains are studied separately, they should be considered in an ergonomic intervention together, as presented in Macroergonomics, proposed by Hendrick (1990).

A method that considers these domains together as one of its premises is the Macroergonomic Analysis of Work (AMT), proposed by Guimarães (2002), based on the socio-technical system, in a participatory approach. AMT aims to identify, monitor and change any situations that compromise the quality of life at work, which can become a risk to the worker's health and a source of reduced productivity.

Another premise of the AMT is the participatory approach, which proposes the participation of workers at all times of the study. According to Nagamachi (1996), "if people in the organization participate in decision-making, they are able to experience the use of their skills and judgment". As a result, this type of situation provides people with a sense of responsibility and commitment to the organization. Studies by Leite *et al.* (2019) and Poncini *et al.* (2019) point out the importance and effectiveness of employee participation in the application of AMT, presenting more realistic results regarding the work situation.

1.1. Goal

This study proposes a way of applying *Lean* and Human Factors through the integration of DMAIC and AMT methods, using both the philosophy and tools of *Lean* and ergonomics and, thus, present the proposal in a practical experimental case.

1.2. Method

In order to meet the proposed objective, it was carried out as an applied research, of a quantitative nature and exploratory objective (NASCIMENTO, 2016). The research followed 3 stages: i) Literature review; ii) Integration of the DMAIC and AMT Methods; and iii) Experimental case following the proposed structure.

2. Development, Results and Discussion

2.1. Integration of Methods

The study on the theoretical bases carried out in the first stage of this research was what led to the development of the model. This model relied on the use of *Lean*, with its tools and philosophies, linked to the studies of Human Factors, which considers the physical, environmental, cognitive, organizational and social aspects for the implementation of improvements in the work system. It should be noted that no explicit application of DMAIC was found in the literature in conjunction with Human Factors tools. Thus, the present research presents means of this joint application representing a contribution to the area of Production Engineering and Ergonomics.

The proposed model was divided into 5 steps that correspond to the steps of the DMAIC. Also, in order to complement the integration of the two methods (AMT and DMAIC), steps and tools were added to comply with the studies and thoughts of *Lean* and Human Factors, as shown in Chart 1.

In the "*define*" stage, the main objective was to define the scope of the project. To do this, the first step is to identify the problem or opportunity for improvement. Next, the survey of information and analysis of the history of the problem that the company has been facing must be carried out, which is consistent with Phase 1 of the AMT until the stage of Survey of Demands, seeking evidence that justifies the realization of the research. However, AMT has Phase 0, which is the launch of the project and thus will be incorporated before Phase 1 in order to obtain the complete integration of AMT with DMAIC.

In the "*measure*" stage, the objective is to understand the processes and their performance. Thus, existing data must be analyzed, verifying its reliability and, defining between the alternatives of collecting new data or using existing data, whether they are reliable and whether they portray the company's reality, which results in the same objective as the rest of Phase 1 of the AMT, that is, prioritization. At the end of this stage of the DMAIC, the problems found in the previous stage should be defined, so that they could be deepened in the subsequent stages.

The "*analyse*" phase is the most important of the method, because it is in this phase that the root causes of the problem are identified. As well as Phase 2 of the AMT (Diagnosis), analyze the variables that generate waste of time and ergonomic risks and, based on them, define which of them would be fundamental causes for research. The root causes are the root causes considered a priority and that are part of the scope of the project, after being defined they move on to the next stages of the DMAIC.

The "*improve*" step focuses on fully understanding the causes identified in the *"analyse*" step in order to control or eliminate those causes to achieve optimal performance. In this stage, possible solutions are proposed (Phase 3 of the AMT) and the elaboration or design (Phase 4 of the AMT) of these solutions along with the table of costs and requirements.

The last stage, "*control*", responsible for documentation and monitoring also meets Phase 5 of the AMT, which seeks to analyze the proposed modifications and make the final changes.

Table 1: Proposed model integrating DMAIC with AMT

DMAIC Method	AMT Method	Tool/Procedures	Goal
Sets	Identification of demand and context	Interviews	Define the scope of the project and the context it is given
	AMT Phase 0: Launch	Meeting	Present the steps and objectives of the DMAIC and AMT stages
	AMT Phase 1: Demand Survey	Interviews	Identify positive and negative items of work
Measure	AMT Phase 1: Prioritization	Application of the ABCORE questionnaire (AMT)	Identify macroergonomic demand items
		Statistical analysis	Evaluate the reliability, stability, and consistency of the data.
		Chart Analysis (AMT)	Interpret priority demand items
	Process mapping	BPMN Modeling	Present a diagram of interactions between systems
	Assessment of critical processes	Direct Observation	Analyze the processes and their operative modes
Analyse	AMT Phase 2: Diagnosis	Application of risk questionnaire (AMT)	Analyze potential ergonomic hazards
		Application of the Couto Checklist	
		Lighting and noise analysis	Measure light intensity, sound intensity and sound frequency
		Temperature analysis	Measure temperature, humidity and calculate relative temperature
		Biochemical Factor Analysis	Identify PPE if appropriate in relation to biochemical agents
		RULA	Evaluate the posture adopted during work
		NIOSH	Evaluate ergonomic cost
		Anthropometric analysis	Compare the worker's body dimensions with the work environment
		Interview about the organization of work	Answer questions regarding the interaction of the system with the human being
		Work Process Analysis (APT)	Analysis of the tasks that add value during the work
		Communication flow	Analyze the flow of communication between those involved in the process.
DMAIC Method	**AMT Method**	**Tool/Procedures**	**Goal**
	Statistical analysis	Cluster analysis of variables	Identify common characteristics between individuals and variables in order to create clusters of clusters by affinity
		Brainstorming	Discuss ideas regarding the causes of problems

	Root Cause Analysis	5 Whys	Stratify root causes
Improve	Analysis of possible solutions (AMT Phase 3)	Ishikawa	Propose possible solutions
		Brainstorming	
		Problem and Solution Correlation Matrix	Perform the correlation between possible solutions and problems
	AMT Phase 4: Design	Description of the proposals	Present the details of the proposed solutions and their benefits.
	Deployment planning	Table of Costs and Requirements	Present the requirements and values necessary for the implementation of the proposals
	Validation of proposals	Meeting	Present and approve proposals for solutions for implementation
	Proposition of future phases	5W1H	Present in the form of an action plan the continuity of the project

Source: The authors, 2023.

2.2. Experimental case

The present experimental case study followed the proposed model and was conducted in a University Hospital in Curitiba with 100% public care linked to the SUS, but its management is carried out by a philanthropic group. This hospital is a reference in trauma care, urgencies and surgical emergencies in the city of Curitiba and the Metropolitan Region. The main sectors of this hospital are: Emergency Room, ICU (Intensive Care Unit), Surgical Center, hospitalization and laboratories. All these sectors work together to offer the best care for patients and in a humanized way.

One of the basic factors for a quality service is the cleanliness of the service places. Cleaning and disinfection of surfaces are elements that converge to the feeling of well-being, safety and comfort of patients, professionals and family members in health services. They also contribute to the control of infections associated with health care, by ensuring an environment with clean surfaces, with a reduction in the number of microorganisms, and appropriate for carrying out the activities developed in these services.

To this end, the hospital's hygiene team plays an important role in the prevention of healthcare-related infections, and it is essential to improve the use of effective techniques to promote cleaning and disinfection of appropriate surfaces. The hospital team under study includes a total of 15 professionals divided into two interspersed shifts (morning and night). The sectors that have the greatest demand for cleaning professionals are the Surgical Center (CC) and the Emergency Room (ER) as they work uninterruptedly and with a high flow of care. Because of this, the work processes of the cleaning team were analyzed to identify opportunities for improvement and propose solutions for such opportunities.

2.2.1. *Sets*

In order to identify the demands and extract the context of this system, the absenteeism and *turnover* rates of the hospital's cleaning team and the infection rate, also called the HAI (Health Care-Associated Infections) rate, where the hospital provided data for the period from January 2015 to August 2019, were analyzed.

By analyzing Table 1, it can be seen that the rates of absenteeism and *turnover* of cleaning employees are high, which can compromise the work of the team, taking into account that there are a total of 15 people in the sector.

Table 1: Hospital *turnover* and absenteeism rate (cleaning staff)

Month	*Turnover* (persons/month)	Absenteeism (persons/month)	Total (persons/month)
January	2,40	4,20	6,60
February	3,70	3,80	7,50
March	1,20	2,10	3,30
April	4,80	2,10	6,90
May	1,20	2,00	3,20
June	1,20	2,70	3,90
July	5,00	2,01	7,01
August	3,03	2,11	5,14

Source: Adapted from HUC, 2019.

Regarding the HAI, this rate is calculated by the number of episodes of hospital infections in the period/total departures (discharges, deaths, transfers), it was possible to infer that the rate is unstable and there was a relative increase compared to the previous month in the vast majority of months. This data emphasizes the importance of the cleaning process and the hospital's cleaning team, which is directly related to infection control, which is a critical success factor in the provision of hospital services.

After analyzing the historical data of the indicators made available by the hospital, it can be defined as an opportunity for improvement the proposal of a solution that optimizes the cleaning processes carried out by the cleaning team, in order to increasingly ensure a cleaner environment for patients. In order to achieve greater assertiveness and agility, it was proposed to work only with the surgical center (SC) cleaning team at first.

To better understand the organization of the hygiene work and the perception of the other departments involved, an interview was conducted with the conviction and supervision of the CC and with the outsourced company that manages the hospital's cleaning.

The interviews were conducted individually and, for each interviewee, the interviewees were asked about the relationship between the departments and the cleaning team. The

information obtained from these interviews is complemented by the data analyzed to seek the main problems, still preliminary, related to the cleaning process.

In the end, the issues that were raised were: i) delay in cleaning environments at the time of shift change; ii) prescribed work is not fulfilled; iii) medical staff becomes contaminated when entering a non-sterile room because they do not have the information; iv) low quality of cleanliness, and; v) lack of labor. These problems were treated as preliminary and should be investigated and proven in the next phases.

After Phase 0 of the AMT (Launch of the project), an initial survey of the problems was carried out and defined by the IDEs (Ergonomic Demand Indexes) directly, through interviews with employees in the sector, and indirectly, through the perception of the researcher and specialists. Direct observation is used in three stages, based on the Macroergonomic Design defined by Fogliatto and Guimarães (1999).

For the initial data collection, recorded interviews were conducted with 6 employees. The recording was authorized by all participants and they were not identified. Then, the statements were analyzed and the positive and negative points mentioned by the interviewees were listed. The order of mention of each item is used as a weight of importance by the reciprocal of the respective position (FOGLIATTO; GUIMARÃES, 1999). Thus, the prioritization rule values the first items mentioned, where it could be seen that the 4 most important items were job satisfaction, the need to go up and down stairs, the relationship with physicians and the rotation in task assignments. The other questions are less relevant compared to the first ones, but all items must be taken into account for the preparation of the questionnaires.

The indirect survey was carried out by the researchers through visits in alternate periods, considering shifts and schedules, making it possible to analyze and identify problems related to the conditions of the environment, the workplace, the organization of work and general aspects of the company.

2.2.2. *Mesure*

This stage is divided between Phase 1 of the AMT (Application of questionnaires and prioritization), the mapping of the processes involved and the evaluation of critical processes. Based on the results of the direct and indirect analyses by the researcher, 3 questionnaires were elaborated. The first questionnaire is given on a satisfaction scale, based on the constructs of ABCORE (Environment, Biomechanical, Cognitive, Organizational and Company) proposed

by Guimarães (2000) totaling 50 questions. The second questionnaire is based on the model proposed by Guimarães (2000) adapted from the *Body Part Discomfort* (BPD) of Wilson and Corlett (1995), which seeks to analyze in more detail the discomfort and pain (Risks) of employees, taking into account the different ages and anthropometric characteristics. Finally, the third questionnaire, made from the first questionnaire, is given on a scale of importance for the questions related to the constructs Environment, Workstation (Biomechanics) and Company. In general, while the interviews generate qualitative data, the questionnaires generate quantitative data because they have a continuous scale of 15 cm for the satisfaction and importance questionnaires and 8 cm for the Corlett questionnaire.

The application was carried out in trios, pairs or individually, depending on the availability of the collaborators. The questionnaires were applied to the population of 15 people over a period of 15 days and the data from the answers were tabulated. To evaluate the reliability and stability of the data, since they are answered individually and by non-scaled measurement, the study of grouping by observations, Cronbach's Alpha coefficient and descriptive statistical analysis was performed. With the results, stability and reliability in the analyses in all questions are verified.

For the analysis of the questionnaires, the degree of prioritization of each of the requirements was calculated, based on the satisfaction and importance of each item of the questionnaires. This indicator was generated from Equation 1, where prioritization considers the discrepancy between the evaluation of importance and satisfaction of each item of the questionnaire.

Equation 1: Degree of prioritization

$$\text{Prioritization} = \frac{((15 - Satisfaction) * Importance)}{15}$$

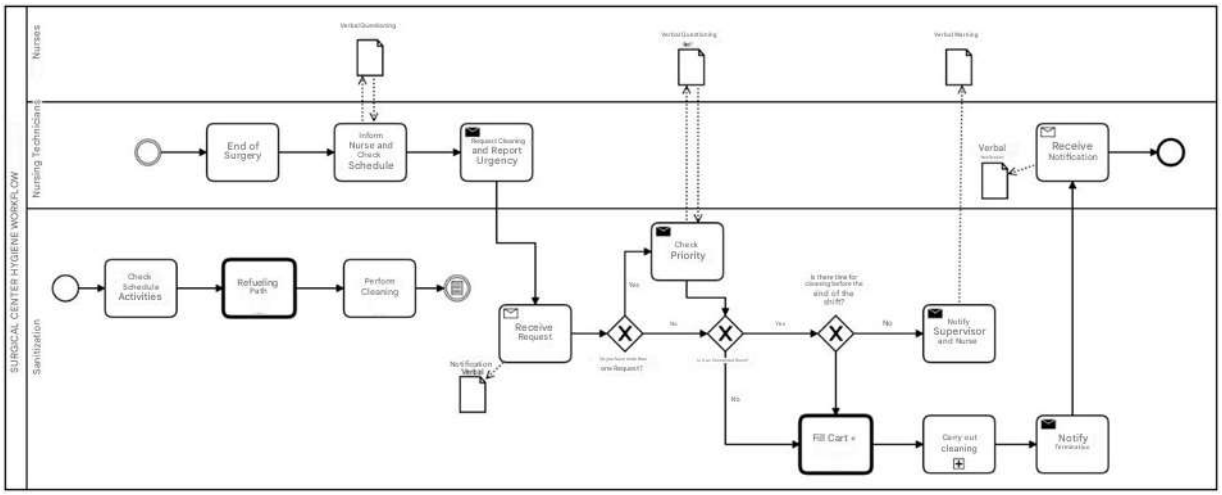
Source: Guimarães *et al.*, 2000.

To complement the analysis of the prioritization of each requirement, critical points were identified, which correspond to items above 7.5 on the importance scale, and items below 7.5 on the satisfaction scale. Thus, the questions considered most important, but with low satisfaction for the respondents, were related to the workplace, followed by questions related to the company. It is noted that for the SC, questions involving physical factors (workstation) (10.8) presented greater dissatisfaction.

After analyzing the graphs, and in order to understand the process flow of the cleaning team, the workflow was mapped based on interviews with employees, analysis of the prescribed

work, and direct observations made by the researcher. Figure 1 shows the workflow of the cleaning team in the CC sector.

Figure 1: Mapping of the BPMN work process of the CC sector



Source: The authors, 2020.

The surgical center has a schedule of tasks for the cleaning team, but there is no prioritization of environments since the volume of occurrences and rooms for cleaning is high. A peculiarity of the sector is that for some types of surgery, those that have some contaminating element, a more careful and thorough cleaning process is necessary, which can take up to four times the time of a normal cleaning.

The fact that this careful cleaning requires much more time to carry out can lead to delays in other activities and, if it is close to the end of the current shift, the rooms are not cleaned and the responsibility is transferred to the next team. In addition, all requests are made completely orally, even when there is more than one demand being requested, which leads the team to go to the nursing room to assess the priority of the tasks.

2.2.3. *Analyse*

In the *Analyse phase* it is important to define the why, where and how problems happen, leading us to the processes that generate problems. With the analyses carried out in the *measure stage,* it was possible to raise possible problems to be investigated and analyzed in order to determine their root causes.

In Phase 2 of the AMT (Diagnosis), in order to stratify the real causes of each requirement, the application of protocols and tools that detail such problems was planned. Chart 1 presents the list of tools applied for each ABCORE factor.

Chart 2: Tools/procedures used in the diagnosis in each ABCORE construct

TOOLS/PROCEDURES	ENVIRONMENT	• Lighting Analysis (LUX) • Noise Analysis (Frequency/ Intensity/ Duration) • Temperature (Temperature/ Variation/ Humidity) • Biochemical Factor Analysis • Couto's Checklist
	BIOMECHANICAL	• NIOSH (Weight) • Anthropometric Analysis (Static and Dynamic) • RULA • Risk Questionnaire • Couto's Checklist
	COGNITIVE	• Couto's Checklist • Variable Grouping Analysis • Communication Flow
	ORGANIZATIONAL	• Work Process Analysis (APT) • Communication Flow • Interview • Couto's Checklist
	RISKS	• Couto's Checklist
	ENTERPRISE	• Maslow's Pyramid • Interviews

Source: The authors, 2020.

The application of these tools helped in the detailing of the possible problems identified, facilitating the proposition of solutions. Considering the problems identified so far in the environmental, biomechanical, cognitive, organizational, risk and company constructs, it was possible to identify risks of repetitive strain injuries (RSI) and possible work-related musculoskeletal disorders (WMSD) in the work process. According to Maeno *et al.* (2006), what explains the high prevalence of these burnouts is mainly the fact that most organizations are characterized by the establishment of goals and productivity, in order to increase market competitiveness, but forget to take into account workers and their physical and psychosocial limits. With these goals, workers are forced to adapt to the organizational characteristics of the companies, leading to a high demand for repetitive movements, absence and impossibility of spontaneous breaks, the need to remain in certain inappropriate positions for a long time, tension, stress and other factors directly or indirectly linked to the physiognomy and functional capacity of the worker that greatly contribute to the existence of RSI or WMSD (MAENO *et al.*, 2006).

In the analysis of the environment it is indicated that air quality and temperature have greater priority, in the investigation of such problems, it was identified that there are problems in temperature and lighting. Even if there is a ventilation system in place, it is ineffective as well as the layout and composition of the lighting system.

The biomechanical analysis identified a greater prioritization regarding the size of the materials, posture and quality of the tools. Analyzing the attitude of the employees in several

tasks, a higher risk was presented in the activities: cleaning the infected room, cleaning the floor and separation of materials. With the APT, it was identified in the process of cleaning the floor that the problem occurs in the twisting of the cloth and in the squatting necessary for such action. In the cleaning of infected rooms, the stretching that is necessary, added to the process of going up and down benches and stairs to clean the ceiling and walls, causes a high risk of RSI and WMSD, in addition to wasting time.

In the cognitive analysis, considering the application of the questionnaire and Couto's checklist, as a result, it can be concluded that the work of the cleaning team is tiring, stressful, repetitive and monotonous. Grandjean (1998) addresses monotonous work in his studies as a complex mental state that presents physical and mental symptoms, such as lethargy, fatigue, decreased state of vigilance and increased reactivity time, thus contributing to lower productivity. According to Iida (2005), stressful work interferes with work performance. Guimarães (2002) also shows that some circumstances favor the state of boredom, such as repetitive work, associated with a low level of difficulty and prolonged activities.

In the organization of work, the items with the highest priority were the number of people to carry out the work, the schedule and the rotation of tasks. Using the APT tool, a lot of time spent on work that does not add value to the cleaning function was evidenced, as well as communication failures between the medical/nursing team and the cleaning team, leading to the perception of the collaborators regarding the lack of people and the inadequate task rotation. Tasks such as cleaning on top of cabinets, transporting products and equipment, or even the lack of adequate equipment to carry out some tasks shows the ineffectiveness of the cleaning work in the face of irrelevant overwork.

The communication of the cleaning teams with the other departments at peak times is compromised, since up to 4 different demands were identified in a short period of time, making it necessary for employees to memorize these demands. Non-urgent demands such as cleaning bathrooms, replacing alcohol, paper and others are also charged several times by different nurses/doctors, even after they have already been completed.

In the Company chart, the change of sector was presented as the items with the highest priority, followed by trust in the company to solve problems and remuneration related to work. In a second application of interviews to deepen these themes, it was identified that the request for change of sector is given in the emergency room and in some hospitalization sectors. This fact is justified by the relationship of some cleaning employees with doctors and nurses or even by the stress generated in the ER. Trust in the company is very low because, according to the

employees, there is a lot of delay or negligence with problem solving. Both issues mentioned and the added remuneration related to work are related to other demands, previously presented by the constructs Environment, Workstation and Work Organization, because the dissatisfaction generated through problems in these directly affects the perception of the total remuneration related to the work system, as well as the lack of confidence in the company.

It is important to emphasize that the wear and tear that comes from environmental, biomechanical, organizational, work content, among others, because they are unnecessary, such as waiting, rework and transportation, generate costs and do not add value to the system, and must be eliminated from the process. In this way, it was possible to list that the main problems that occur with the cleaning team are: i) inadequate lighting; ii) high temperatures causing thermal discomfort; iii) current equipment does not meet the need; iv) current equipment presents ergonomic risk; v) execution of tasks that do not add value to hygiene; vi) delay in carrying out cleaning tasks; vii) forgetting to carry out cleaning tasks; viii) repeated requests for cleaning of the same place, and; ix) the services performed do not meet the prescribed criteria in quality.

In order to stratify the root causes of the problems, brainstorming was carried out followed by the 5 Whys tool for each ABCORE construct. Thus, the root causes of the problems are: i) there are no transfers from the federal government for infrastructure; ii) manual processes are required to prepare the equipment; iii) poorly dimensioned equipment and furniture characteristics; iv) there is no room cleaning request indicator; v) there is no indication of whether the room is clean or not; vi) there is a lack of structure and there are non-contact areas that need to be cleaned; vii) the 8-hour shift ends at 5 p.m.; viii) there is a greater demand for fewer employees.

Due to the magnitude of the first root cause and because it is not part of the scope of this project, this item was left indicated to the hospital's sponsoring institution for possible future investments.

2.2.4. *Improve*

With a brainstorming, it was possible to present solutions that involved three main aspects: information (I), ergonomic adequacy of tools (E) and time for cleaning (T), and some solutions may have more than one aspect. The proposed solutions were: i) *kanban* for transporting information from clean or infected rooms (I); ii) revision of the schedules and schedules of the cleaning team (I/T); iii) acquisition of industrial MOP with wringing bucket

and extendable cable (E/T); iv) adjustment of the height of the cabinet in the DML (E); v) cabinet to store cleaning materials at the bottom of the CC (E/T); vi) cover the top of the locker room of the CC (E/T).

2.2.5. *Control*

With the proposed improvements, cycle time was reduced by 52.29%, elimination of 12 hours per month of non-value-adding activities, and also intangible benefits such as the reduction and elimination of activities with ergonomic risks, balancing the workload and the aggregation of visual management. It was emphasized that the proposed improvements contribute financially to the hospital, both in process efficiency and in the improvement of the working conditions and health of the cleaning employees, since the gain in cleaning time impacts all stakeholders, and therefore, with the agility in the release of an infected environment, more care can be performed, and it also contributes to the mitigation of cases of hospital infections (HAIs) and other diseases. All changed processes have been documented by the hospital's quality department, but it has not yet been possible to obtain new data regarding *turnover*, absenteeism and HAI for comparison with previous data.

3. CONCLUSION

With this research, a model was proposed that integrates *Lean* with Ergonomics/human factors, through DMAIC and AMT, respectively. This model considers *Lean*, with its tools and philosophies, linked to the studies of Human Factors, which considers physical, environmental, cognitive, organizational and social aspects for the implementation of improvements in the work system. This model was applied in an experimental study in a hospital, which helped the development of a more effective process, with shorter cycle time, less waste and better working conditions for those involved. It is recommended that studies and interventions involving both approaches be continued in order to improve the efficiency and effectiveness of companies, also in the service area and, especially, in companies in the hospital area.

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REFERENCES

ABERGO. **O que é ergonomia**. Disponível em: <www.abergo.org.br>. Acesso em: 20 Out. 2019. BATALHA, Mário Otávio de. **Introdução à Engenharia de Produção**. Rio de Janeiro: Elsevier, 2008.

Fogliatto, F. S.; Guimarães, L. B. de M. (1999). **Design Macroergonômico: uma proposta metodológica para o projeto de produto**. Produto e Produção, Porto Alegre.

GARBUIO, Paula Andrea da Rosa. **As diferenças na gestão das organizações que utilizam os modelos *lean* manufacturing, seis sigma e *lean* seis sigma como estratégia de operações**. 2010. 163 f. Dissertação (Mestrado) - Curso de Engenharia de Produção e Sistemas, Pontifícia Universidade Católica do Paraná, Curitiba, 2010

GRANDJEAN, E. (1998). **Manual de ergonomia. Adaptando o trabalho ao homem**. Porto Alegre: Artes médicas.

GUIMARÃES, L. B. de M. (2000). **Ergonomia de Processo 1**. 3 ed. Porto Alegre, RS, Federal University of Rio Grande do Sul - Graduate Program Graduation in Production Engineering.

GUIMARÃES, L. B. de M. (2004). **Ergonomia de Processo 2**. 4 ed. Porto Alegre, RS, Federal University of Rio Grande do Sul - Graduate Program Graduation in Production Engineering.

GUIMARÃES, Lia B. M**. Macroergonomia: Colocando conceitos em prática**. Vol. 1. Porto Alegre: UFRGS/FEENG, 2010.

GUIMARÃES, Lia Buarque de Macedo. **Análise Macroergonômica do Trabalho – AMT. Modelo de implementação e avaliação de um programa de ergonomia da empresa**. 2002. Artigo não publicado

HENDRICK, H. W. **Macroergonomics: a system approach to interacting human factors with organizational design and management**. In: Annual conference of the human factors association of canada, 23, 1990, Otawa. **Proceedings Otawa: HFAC**

IEA. **What is ergonomics?** 2000. Disponível em: <http://www.iea.cc/browse.php?contID=what_is_ergonomics>. Acesso em: 04 out. 2019.

IIDA, Itiro. **Ergonomia: Ergonomia: Projeto e Produção**. São Paulo: E. Blücher, 4ª Ed., 1997 IIDA, Itiro. **Ergonomia: projeto e produção**. 2. ed., rev. e ampl. São Paulo: E. Blücher, 2005

LEITE, L. O. M.; SASAKI, A. M.; CANCIGLIERI JUNIOR, O.; and BITENCOURT, R. S. (2019). **Análise macroergonômica do trabalho: estudo de caso no setor de faturamento de um hospital universitário do paraná**. In: XIX Congresso Brasileiro de Ergonomia

MAENO, Maria; SALERNO, Vera; ROSSI, Daniela A. G.; FULLER, Ricardo. (2006) **LER e DORT dor relacionada ao trabalho**. Disponível Em: < http://bvsms.saude.gov.br/bvs/publicacoes/protocolo_ler_dort.pdf >. Acesso em: Nov, 2019.

NAGAMACHI, M. (1996). **Relationship between Job Design, Macroergonomics, and Productivity**. International Journal of Human Factors in Manufacturing, Higashi-Hiroshima, v. 6, n. 4, p.309-322.

OHNO, T. **O Sistema Toyota de Produção: além da Produção em Larga Escala**. Porto Alegre: Bookman, 1997.

PONCINI, C. R.; BITENCOURT, R. S.; OKUMURA, M. L. M.; and CANCIGLIERI Junior, O. (2019). **Análise macroergonômica no laboratório de uma instituição de ensino superior do paraná**. In: XIX Congresso Brasileiro de Ergonomia e XII Fórum de Certificação do Ergonomista - ABERGO, 19 ed., Curitiba. Anais... . Curitiba: Scienza.

WERKEMA, Maria Cristina Catarino. **Criando a cultura Seis Sigma**. Nova Lima: Werkema, 2004.

WILSON, J. R.; CORLETT, E. N. (Eds.). (1995). **Evaluation of human work: A practical ergonomics methodology** (2nd ed.). Philadelphia, PA, USA: Taylor & Francis.

WOMACK, J. P.; BYRNE, A. P.; FIUME, O. J.; KAPLAN, G. S.; TOUSSANT, J.; MILLER, D. **Going *lean* in healthcare**. Innovation series 2005, Institute for Healthcare Improvement, 2005.

WOMACK, J.; JONES, D.; ROSS, D. **A máquina que mudou o mundo**. Rio de Janeiro: Campus-Elsevier, 2004. WOMACK, James P.; JONES, Daniel T. ***Lean* Thinking**: Banish Waste and Create Wealth in Your. New York: USA: Simon & Schuster, Inc., 1996