https://doi.org/10.4322/rae.v17n2.e202312.en

ABERGO 2023
XXIII CONGRESSO BRASILEIRO DE ERGONOMIA
XVI FÓRUM DE CERTIFICAÇÃO DO ERGONOMISTA BRASILEIRO
XVII FÓRUM DOS GRUPOS TÉCNICOS DA ABERGO

Lean Thinking and Human Factors: a proposed model and application in a hospital

Cristoffer Rodrigues Poncini – Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS – Curitiba – PR – Brasil – cristoffer0087@gmail.com
Camilla Buttura Chrusciak - Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS – Curitiba – PR – Brasil – butturacamilla@gmail.com
Rosimeire Sedrez Bitencourt – Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS – Curitiba – PR – Brasil – rosimeire.bitencourt@pucpr.br
Osiris Canciglieri Junior – Pontifícia Universidade Católica do Paraná, Núcleo SEEDS, PPGEPS – Curitiba – PR – Brasil – osiris.canciglieri@pucpr.br

Summary

The application of Lean can change the way people work and, when Ergonomics/Human Factors are not properly observed, negative impacts can occur both on the human well-being of workers and on the work system as a whole. Therefore, this article aims to present a proposal for integration between 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 exploratory objectives. This research followed 3 stages: i) Literature review; ii) Integration of 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, resulting in gains in several aspects. It is recommended that studies and interventions continue that involve both approaches 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 seeks to improve processes, bringing greater efficiency to the system and lower costs, which can contribute to the health sector. 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 for goods and services, involving men, materials, technology, information and energy.” The tools used to improve processes are distributed across the various areas of its competence, such as the management of financial, human and material resources, as well as the association of administration techniques, engineering knowledge and economic fundamentals (BATALHA, 2008).

Among the various improvement tools, philosophies and methodologies, Lean stands out as a philosophy that can be applied in different areas with the aim of reducing waste and improving system efficiency. Lean Manufacturing emerged from 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 the absolute elimination of waste and Just-in-time (JIT). 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 way of improving systems.

Lean addresses several process analysis and improvement tools. One of the tools used within this philosophy, which aims to improve the process through steps and problem solving arranged in a cyclical and continuous manner, 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, with workers finding work much more stimulating, but at the same time finding their tasks more stressful” . This occurs because the Lean philosophy does not fully encompass the vision of Ergonomics/Human Factors (EFH) applied to the workers involved in the process.

According to Iida (1997), prolonged stress begins to influence work performance, reducing productivity and quality, and may also increase the risk of accidents, absenteeism and worker turnover. In this context, Human Factors that incorporate the environment, workplace, work organization and work content, 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 (Human Factors) and, according to the IEA (International Ergonomics Association) (2000), it is the scientific discipline related to the understanding of interactions between humans and other elements of a system, contributing

thus for the project of evaluating work, tasks, products, environment, aiming to make them compatible with the abilities, needs and limitations of human beings. Ergonomics, according to ABERGO (2019), has 3 domains of specialization, namely: physical, cognitive and organizational. Although these domains are studied separately, they must be considered in an ergonomic intervention together, as presented in Macroergonomy, proposed by Hendrick (1990).

A method that considers these domains together as one of its premises is the Macroergonomic Work Analysis (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 could become a risk to worker health and a source of reduced productivity.

Another premise of 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 feeling 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, presenting 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 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 included the use of Lean, with its tools and philosophies, linked to Human Factors studies, which considers physical, environmental, cognitive, organizational and social aspects to implement improvements in the work system. It is worth noting that no explicit application of DMAIC in conjunction with Human Factors tools was found in the literature. 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 DMAIC steps. Furthermore, in order to complement the integration of the two methods (AMT and DMAIC), steps and tools were added to comply with Lean and Human Factors studies and thoughts, as presented in Table 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, information must be collected and the history of the problem that the company has been facing must be analyzed, which is consistent with Phase 1 of the AMT until the Demand Survey stage, seeking evidence that justifies carrying out the research. However, AMT has Phase 0 which is the launch of the project and will therefore be incorporated before Phase 1 in order to obtain complete integration of AMT with DMAIC.

In the "measure" stage, the objective is to understand the processes and their performance. Therefore, existing data must be analyzed, checking 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 focus problems found in the previous stage must be defined, so that they can be deepened in the subsequent stages.

The "analysis" phase is the most important of the method, as it is here that the root causes of the problem are identified. As well as Phase 2 of 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 the research. Fundamental causes are the root causes that are considered priorities and are part of the scope of the project. Once defined, they proceed to the next stages of DMAIC.

The “improve” stage focuses on fully understanding the causes identified in the “analyze” stage with the aim of controlling or eliminating such causes to achieve optimized performance. At this stage, possible solutions are proposed (Phase 3 of the AMT) and the elaboration or design (Phase 4 of the AMT) of these solutions together with the table of costs and requirements.

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

Quadro 1: Modelo proposto integrando DMAIC com AMT

DMAIC method	**AMT Method**	**Tool/Procedures**	**Goal**
Define	Identification of demand and context	Interviews	Define the scope of the project and the context in which 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 work items
Measure	AMT Phase 1: Prioritization	Application of the ABCORE (AMT) questionnaire	Identify macroergonomic demand items
		Statistical analysis	Assess data reliability, stability and consistency.
		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 operating modes
Analyse	AMT Phase 2: Diagnosis	Application of risk questionnaire (AMT)	Analyze possible ergonomic risks
		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
		Analysis of biochemical factors	Identify PPE if appropriate in relation to biochemical agents
		RULA	Evaluate the posture adopted during work
		NIOSH	Assess the ergonomic cost
		Anthropometric analysis	Make a comparison between the worker’s body dimensions and the work environment
		Interview about work organization	Resolve doubts regarding the interaction of the system with humans

DMAIC method	AMT Method	Tool/Procedures	Goal
		Work process analysis (APT)	Analysis of tasks that add value during work
		Communication flow	Analyze the flow of communication between those involved in the process.
	Statistical analysis	Variable cluster analysis	Identify common characteristics between individuals and variables in order to create affinity grouping clusters
	Root Cause Analysis	Brainstorming	Discuss ideas regarding the causes of problems
		5 Whys	Stratify root causes
Improve	Analysis of possible solutions (AMT Phase 3)	Ishikawa	Propose possible solutions
		Brainstorming	
		Problem and solution correlation matrix	Correlate possible solutions and problems
	AMT Phase 4: Design	Description of proposals	Present details of proposed solutions and their benefits.
	Deployment planning	Table of Costs and Requirements	Present the requirements and values necessary for implementing the proposals
	Validation of proposals	Meeting	Present and approve solution proposals for implementation
	Proposal of future phases	5W1H	Present the continuity of the project in the form of an action plan

Source: The authors, 2023.

2.2 Experimental case

The present experimental case study followed the proposed model and was conducted in a University Hospital of Curitiba with 100% public service linked to the SUS, but its management is carried out by a philanthropic group. This hospital is a reference in trauma care, urgent care 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 in a humanized way.

One of the basic factors for a quality service is the cleanliness of the service areas. Cleaning and disinfecting surfaces are elements that contribute to the feeling of well-being, safety and comfort of patients, professionals and families in healthcare services. They also contribute to the control of infections related to healthcare, by ensuring an environment with clean surfaces, with a reduction in the number of microorganisms, and appropriate for carrying out the activities carried out in these services.

To this end, the hospital's hygiene team plays an important role in preventing infections related to healthcare, and it is essential to improve the use of effective techniques to promote

adequate cleaning and disinfection of surfaces. The hospital team under study comprises a total of 15 professionals divided into two alternating 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 operate uninterruptedly and with a high flow of services. Because of this, the work processes of the hygiene team were analyzed to identify opportunities for improvement and propose solutions for such opportunities.

2.2.1 Define

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

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

Table 1: Hospital turnover and absenteeism rate (cleaning team)

Mês	***Turnover (people/month)***	**Absenteeism (people/month)**	**Total (people/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.

In relation to IRAS, this rate is calculated by the number of episodes of hospital infections in the period/total number of 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 large most months. This data emphasizes the importance of the cleaning process and the hospital's hygiene 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, the proposal for a solution that optimizes the cleaning processes carried out by the hygiene team can be defined as an opportunity for improvement, in order to increasingly guarantee a cleaner

environment for patients. patients. In order to obtain greater assertiveness and agility, it was proposed to work only with the surgical center (SC) hygiene team at first.

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

The interviews were carried out individually and, for each interviewee, the interviewees were asked about the relationship between the departments and the hygiene team. The information obtained from these interviews is complemented with the data analyzed to identify 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 carried out; iii) medical staff become contaminated when entering a non-sterilized room because they do not have the information; iv) poor quality of cleaning, and; v) lack of labor. These problems were treated as preliminary and must be investigated and proven in the next phases.

After Phase 0 of the AMT (Project Launch), 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 experts. Direct observation is used in three stages, based on the Macroergonomic Design defined by Fogliatto and Guimarães (1999).

For initial data collection, recorded interviews were carried out 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 cited 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 was clear that the 4 most important items were job satisfaction, the need to go up and down stairs, the relationship with doctors and taking turns in task assignments. The remaining questions are less relevant compared to the first, but all items must be taken into consideration when preparing the questionnaires.

The indirect survey was carried out by researchers through visits at alternating 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 AMT (Application of questionnaires and prioritization), mapping of the processes involved and assessment of critical processes. Based on the results of the direct and indirect analyzes by the researcher, 3 questionnaires were created. The first questionnaire is given on a satisfaction scale, based on the ABCORE constructs (Environmental, 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) by Wilson and Corlett (1995), which seeks to analyze in more detail the discomfort and pain (Risks) of employees, taking taking into account different ages and anthropometric characteristics. Finally, the third questionnaire, created based on the first questionnaire, is given on a scale of importance for questions related to the constructs Environment, Workplace (Biomechanical) and Company. In general, while interviews generate qualitative data, questionnaires generate quantitative data as 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 administered to a population of 15 people over a period of 15 days and the response data was tabulated. To assess the reliability and stability of the data, since these are answered individually and through non-scaled measurement, a grouping study was carried out using observations, Cronbach's Alpha coefficient and descriptive statistics analysis. The results show stability and reliability in the analyzes on all questions.

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

Equation 1: Degree of prioritization

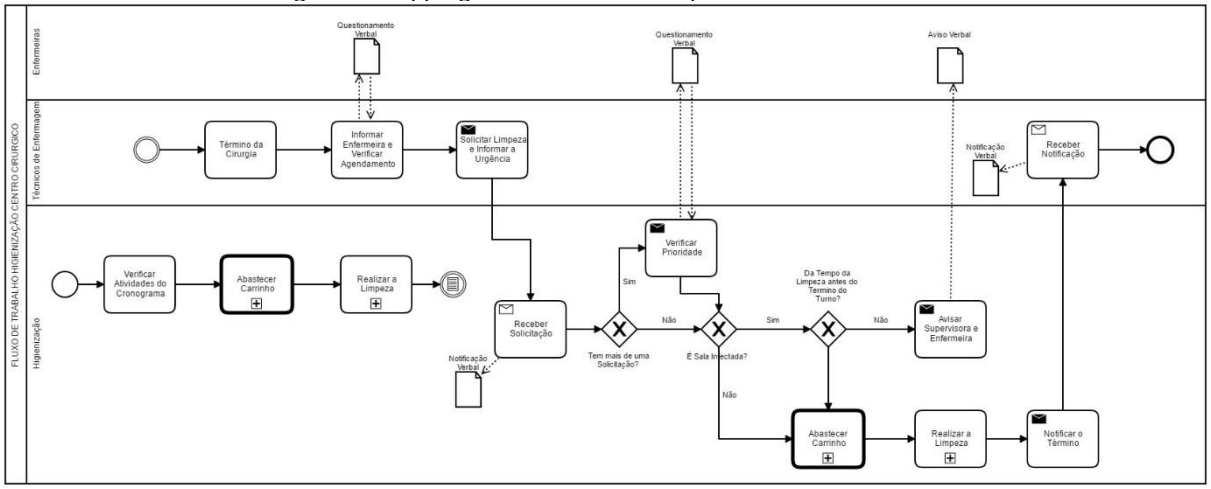
$$Prioritization = \frac{((15 - Satisfaction) * Importance)}{15}$$

Source: Guimarães et al., 2000.

To complement the analysis of the prioritization of each requirement, critical points were identified that 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 respondents, were in relation to the job, followed by questions related to the company. It is noted that for the CC, issues involving physical factors (workplace) (10.8) presented greater dissatisfaction.

After analyzing the graphics, and 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 carried out by the researcher. Figure 1 shows the workflow of the CC sector hygiene team.

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



Source: The authors, 2020.

The surgical center has a task schedule for the cleaning team, but there is no prioritization of environments since the volume of incidents and rooms for cleaning is high. A peculiarity of the sector is that for some types of surgery, those that contain some contaminating element, a more careful and thorough cleaning process is necessary, which can take up to four times the time of 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. Furthermore, all requests are made entirely 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 Analyze phase, it is important to define why, where and how problems occur, leading us to the problem-generating processes. With the analyzes carried out in the measure stage, it was possible to identify possible problems to be investigated and analyzed in order to determine their root causes.

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

Table 2: Tools/procedures used in diagnosis in each ABCORE construct

TOOLS/PROCEDURES	ENVIRONMENT	• Lighting Analysis (LUX) • Noise Analysis (Frequency/Intensity/Duration) • Temperature (Temperature/ Variation/ Humidity) • Analysis of Biochemical Factors • Couto Checklist
	BIOMECHANICS	• NIOSH (Weight) • Anthropometric Analysis (Static and Dynamic) • RULA • Risk Questionnaire • Couto Checklist
	COGNITIVE	• Couto Checklist • Cluster Analysis by Variables • Communication Flow
	ORGANIZACIONAL	• Work Process Analysis (APT) • Communication Flow • Interview • Couto Checklist
	scratchs	• Couto Checklist
	COMPANY	• Maslow's Pyramid • Interviews

Source: The authors, 2020.

The application of these tools helped to detail the possible problems identified, making it easier to propose solutions. Considering the problems identified so far in the environmental, biomechanical, cognitive, organizational, risks 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 this attrition is mainly the fact that most organizations are characterized by setting goals and productivity, in order to increase market competitiveness, but forget to take

into account workers and their employees. physical and psychosocial limits. With these goals, workers are forced to adapt to the organizational characteristics of companies, leading to a high demand for repetitive movements, the absence and impossibility of spontaneous breaks, the need to remain in certain inappropriate positions for a prolonged period of time, tension, stress and other factors directly or indirectly linked to the physiognomy and functional capacity of the worker, which 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 higher priority, in the investigation of such problems, it was identified that there are problems with temperature and lighting. Even if there is a ventilation system in operation, it is ineffective, as is the arrangement and composition of the lighting system.

The biomechanical analysis identified a greater prioritization regarding the size of materials, posture and quality of tools. Analyzing the employees' posture in various tasks, a greater risk was presented in the activities: cleaning the infected room, cleaning the floor and separating materials. With APT, it was identified in the floor cleaning process that the problem occurs with the twisting of the cloth and the squatting required for this action. When cleaning 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 WMSDs in addition to wasted time.

In the cognitive analysis, considering the application of the questionnaire and the Couto 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 vigilance and increased reactivity time, thus contributing to a lower productivity. According to Iida (2005), stressful work interferes with work performance. Guimarães (2002) also shows that some circumstances promote a state of boredom, such as repetitive work, associated with a low level of difficulty and prolonged activities.

In the organization of work, the highest priority items were the number of people to carry out the work, the schedule and the rotation of tasks. Using the APT tool, it was evident that a lot of time was spent on work that does not add value to the cleaning function and also communication failures between the medical/nursing team and the hygiene team, leading to employees' perception of the lack of number of people and inappropriate task rotation. Tasks such as cleaning cabinets, transporting products and equipment, or even the lack of adequate

equipment to carry out some tasks shows the ineffectiveness of hygiene work in the face of irrelevant excess work.

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

In the Company graph, change of sector was presented as the highest priority items, followed by trust in the company to solve problems and remuneration related to work. In a second interview to delve deeper into these themes, it was identified that the request to change sectors is made in the emergency room and in some hospitalization sectors. This fact is justified by the relationship between some sanitation workers and doctors and nurses or by the stress generated in the ER. Trust in the company is very low because, according to employees, there is a lot of delay or negligence in resolving problems. Both the aforementioned issues and the work-related remuneration are related to other demands, previously presented by the constructs Environment, Workplace and Work Organization, as dissatisfaction generated through problems in these directly affects the perception of total remuneration related to the system. of work, as well as the lack of trust in the company.

It is important to highlight that the wear and tear that comes from environmental, biomechanical, organizational factors, work content, among others, as 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 hygiene team are: i) inadequate lighting; ii) high temperatures causing thermal discomfort; iii) current equipment does not meet the need; iv) current equipment presents ergonomic risks; v) carrying out 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 to clean the same location, and; ix) the services performed do not meet the prescribed quality criteria.

In order to stratify the root causes of the problems, brainstorming was carried out followed by the 5 Whys tool for each ABCORE construct. Therefore, the root causes of the problems are: i) there are no funds from the federal government for infrastructure; ii) manual processes are necessary to prepare the equipment; iii) poorly sized 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 5pm; 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 to the institution that maintains the hospital for possible future investments.

2.2.4 Improve

By carrying out brainstorming, it was possible to present solutions that involved three main aspects: information (I), ergonomic adaptation of tools (E) and cleaning time (T), with some solutions having more than one aspect. The proposed solutions were: i) kanban for transporting clean or infected room information (I); ii) review of the cleaning team (I/T) schedules and schedules; iii) acquisition of an industrial MOP with wringer bucket and extendable cable (E/T); iv) cabinet height adjustment in DML (E); v) cabinet to store cleaning materials in the lower part of the CC (E/T); vi) cover the top of the locker in the CC (E/T) changing rooms.

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 aggregation of visual management. It was highlighted that the proposed improvements contribute financially to the hospital, both in process efficiency and in improving the working conditions and health of cleaning employees, since the gain in cleaning time impacts all stakeholders, and therefore , by speeding up the release of an infected environment, more care can be provided, and also contributes to the mitigation of cases of hospital-acquired infections (HAIs) and other diseases. All changed processes were documented by the hospital's quality department, but it was not yet possible to obtain new data regarding turnover, absenteeism and IRAS 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 Human Factors studies, which considers the physical, environmental, cognitive, organizational and social aspects to implement improvements in the work system. This model was applied in an experimental study in a hospital, which helped to develop a more effective process, with shorter cycle time, less waste and better working conditions for those involved. It is recommended that studies and interventions continue that involve both approaches in order to improve the efficiency and effectiveness of companies, also in the service sector and, especially in companies in the hospital sector.

ACKNOWLEDGMENTS

The authors are especially grateful for the support from the Pontifical Catholic University of Paraná (PUCPR) - Escola Politécnica - Postgraduate Program in Engineering Production and Systems (PPGEPS).

4. Bibliographic 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