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METODOLOGIAS ERGONÔMICAS NA AVALIAÇÃO DE AMBIENTE CONSTRUÍDO ERGONOMIC METHODOLOGIES FOR THE EVALUATION OF BUILT ENVIRONMENT

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Abstract

This paper dialogues with the "Question of method", the current issue of V!RUS journal, by explaining and discussing methods adopted in the fields of Ergonomics that have been introduced, in the last decades, into environmental studies. Methodologies of ergonomic analysis aim, first and foremost, to assess work situations. However, the adaptations and adjustments made for environmental studies have shown good results. The present study addresses three methodologies of ergonomics used to assess built environments. Hypotheses for the analysis of situations were made to demonstrate the application of these methodologies in all their stages and present the main results that can be extracted from them. The text deals with the relationship between ergonomics and architecture, which has been studied for some decades and provides elements to prompt and expand the discussion on this topic. The set of material presented fulfills the objective of identifying differences or similarities between different methodologies applied in ergonomic analyses of environments. Such studies are an integral part of research studies that develop, test, and validate tools for assessing environments focusing on Ergonomics.

Keyword: Ergonomic methodologies, Ergonomics of the built environment, Ergonomic analyses of environments, Ergonomics and projects, Ergonomics and

1 Introduction

Researches on the built and inhabited environment have been incorporating the ergonomic perspective into its studies, based on the understanding of the systemic approach advocated by Ergonomics and consequently recognizing its importance. The use of ergonomic concepts and applications in studies of the built environment has been increasingly adopted, whether by using specific methodologies, adopting a multimethod approach, or even applying the combination of different tools. The application of the systematizing view can be identified in a significant number of studies about Ergonomics of the Built Environment (EAC, in Portuguese). This aggregation of methods, methodologies, and procedures enshrined in ergonomic studies and adjusted and adapted to incorporate ergonomic vision into the studies of the built environments, match up to the reflections presented in this issue of V!RUS. Question of method is the scope of this article, especially when presenting and reflecting on ergonomic procedures applied for the evaluation of the environment.

Ergonomics, which was originally considered the science of work and aims to adjust all situations of the development of work to human beings, has expanded its range of action and encompasses all segments in which people carry out activities. The use of the term Ergonomics is related to comfort, well-being, total suitability for human beings, whether it be tools, jobs, environments, or other elements of the system into which people are situated. Ergonomics is commonly defined as the scientific study of the relationship between human beings and their work environment. The term environment encompasses not only the environment in which the human being works but also the instruments, raw materials, methods, and organization of this work. According to the definition of the International Ergonomics Association (IEA, 2014), ergonomics (or human factors) is the scientific discipline related to the understanding of the interactions between human beings and other system elements, thereby providing theoretical principles, data, and methods to design and optimize the human well-being and overall system performance.

It is not possible to think of ergonomics applied to the built environment without considering the various variables involved in the Human-Activity-Environment relationship. This includes the layout of the place, its dimension, the space for activities, environmental comfort, safety, user perception, accessibility, universal design, and the inclusion of everybody without the necessity of adjustments characterized as improvised solutions, including people with physical or mental limitations. It comprises a discourse of design solutions that serve everyone, regardless of their individual state of well-being, and may facilitate the use and promote pleasure (Villarouco, 2018). Research developed by groups dedicated to the study of ergonomics applied to the built environment, such as Attaianese and Duca (2012), Hugine, Guerlain and Hedge (2012), Oliveira (2016), Parsons (2000), Sarmento (2017), Villarouco (2008, 2009), have investigated technologies and methodologies adopted in studies of ergonomics, design, architecture, environmental psychology, and brought them to the discussion of the built environment based on ergonomics. These studies present important contributions, notably by introducing recent methodologies and technologies into the production of environmental studies.

Therefore, this work aims to answer the question: what elements can underpin the definition of the methodology to be adopted for evaluating built environments from the perspective of Ergonomics? To obtain the answer, the objective was to identify differences or similarities between ergonomic analyses of environments conducted based on different methodologies, which delineate the criteria of applicability. This article presents results from some of the studies that have been conducted by the research group "Ergonomics Applied to the Built Environment", of the Federal University of Pernambuco - UFPE.

2 Methodologies in ergonomics applied to built environments

Ergonomic analysis methodologies are valuable tools applied to understand and identify the factors involved in human activities in the built environment. However, there are many variables for taking into consideration when seeking to identify the adequate performance of a built environment, which makes the task of assessing such adequacy complex (Villarouco, 2008), as condensed in Table 1.

Groups of analysis	Factors of analysis
Accessibility	Spatial orientation, communication, use and dislocation
Environmental Comfort	Lighting, thermal and acoustic
Environmental perception	Cognitive and sensory aspects
Suitability of materials	Cladding and finishing, colors and textures
Sustainability	Life-cycle, cost, maintenance and environmental impacts
Anthropometric factors	Layout, dimensioning and furnishings

Table 1: Analysis groups and respective factors of ergonomic analysis in environments. Source: Sarmento (2017) adapted from Villarouco (2011).

The ergonomic approach seeks to improve interactions between various systems and humans to make human activities more efficient, safe, comfortable, and satisfying. Using an ergonomic approach to focus on the interactions between the environment and the user requires examining the effects of the environment on the person that uses it, including the nature of human beings, i.e., their skills, abilities, and limitations (Attaianese and Duca, 2012). Ergonomic methodologies have a scientific character. They work systematically and focus on human beings in real work situations aiming to improve the process in terms of comfort, safety, and efficiency. Using the ergonomic analysis of the environment to verify the relationship between the elements of architecture and the performance of the activities developed inside them requires being familiar with the factors that provide the relationship between people and the environment. According to Santos and Fialho (1997), a work situation is a place where social and technological phenomena occur simultaneously, requiring Ergonomics to behave as a social, biological, and exact science. Thus, according to the authors, the ergonomic analysis must consider the knowledge of these three areas in its stages, and incorporate research procedures from these fields considering them as aids in the compilation of a theoretical/methodological reference structure, both in the analysis and ergonomic synthesis of the work situation.

When performing an ergonomic analysis of the task in a given work environment, the ergonomist reveals some factors that determine the activity and which the worker would not be able to describe. At the same time, it reveals aspects unknown to company managers and designers, such as specific strategies adopted to anticipate and manage incidents and competencies, which are put into action to deal with unexpected events (Monteiro and Lima, 2009). As they deal with the different aspects that encompass the relationship between the individual and his environment in different ways, the analytical look is directed to different ergonomic methodologies. Therefore, a question arises: what would be the most appropriate approach to analyze a physical environment? To assist this choice, the authors carried a comparative study between three methodologies of ergonomic analysis that focus on the built environment from different angles:

i. Macroergonomic Analysis - AMT (Guimarães, 2010). According to Iida (2005), macroergonomics can be defined as the development and application of the technology of the human-machine interface at the macro level i.e., in the entire organization that houses the activity. Ergonomics participates in the design and management of actions by acting on the direction of the company, reflecting on the level of employment, qualification, organization of production, and making of investments, which may result in improvements of a greater extent than in the micro approach i.e., in the workplace. Macroergonomics emphasizes the interaction between the organizational and psychosocial contexts of a system, aiming to better adapt processes and design new systems. Among the methods adapted to implement Ergonomics, the participatory process is one of the most important. The participation of individuals reduces the possibility of design errors and ensures that workers more readily accept the new system implemented (Guimarães, 2004).

Bugliani (2007) reminds us that "the construction of the principles of Macroergonomics comes from articles by Hendrick (1991, 1993, 1995) and (Hendrick, 1996 apud Meister, 1999) published in the magazine *Ergonomics*" (Bugliani, 2007, p. 6). The macroergonomic approach is present in several models and characterized by the global approach. Hendrick (1991) cites methodologies described in the ODAM International Symposia, in 1990, involving the concepts of ODAM (Organizational Design and Management), which contemplates the systemic approach. Bugliani (2007) adds that Guimarães (1999) developed the method of Macroergonomic Analysis of Work (AMT, in Portuguese) covering the analysis of the conditions of the physical environment, jobs, and organizational factors, and involving issues related to the layout, pace, and routines of work, thereby complying with Hendrick's precepts.

ii. The approach of the Human-Task-Machine System - HTMS (Moraes and Mont'alvão, 2007). The concept of a system applies to human performance by defining it in terms of an organized whole, observing the person-centered approach that controls the system. Thus, for the effectiveness of the system, it must be designed from the operator's point of view. Moraes and Mont'alvão (2007) built the Human-Task-Machine

System - HTMS, an expansionist, behavioral, and informational systemic model whose focus is on the individual. In HTMS, information processing is based on skills; the task activities act as an expression of the interaction between information devices; the expansionism of the model is influenced by the physical and organizational environment; and the ergonomic efficiency privileges the economy of the human being by minimizing the human costs of labor.

iii. The Ergonomic Methodology for the Built Environment - MEAC, in Portuguese (Villarouco, 2008, 2009). Having as its main focus the human user of space, Villarouco (2008) assumes that the aspects involved in making the environment suitable must come from the feeling that the user experiences in his/her daily interaction with the environment. Taking the model of the Ergonomic Analysis of Work - AET in Portuguese as a starting point, which is found in Santos and Fialho (1997), the Ergonomic Methodology for the Built Environment - MEAC seeks to establish an analogy between the phases of traditional analysis and those needed to evaluate the space focused on the activity developed there. When applying the methodology, it is found that some interactions may be harmful to the individual, to the system, to productivity, or, in the opposite direction, some elements that can lead to improving the conditions of using the space.

Although this article deals with methodologies developed in Brazil, it also possible to identify, in the international scenario, initiatives for assessing environments under the focus of Ergonomics and which propose methodologies or appropriate a set of combined tools to achieve the objectives. Such experiences are recorded in publications of scientific events in the area of Ergonomics, held by international associations, such as the HFES Annual Meeting (Human Factors and Ergonomics Society), IEA Congress (International Ergonomics Association), AHFE Conference (Applied Human Factors and Ergonomics), ICEE Conference (International Conference on Environmental Ergonomics), in addition to the periodicals *Ergonomics, Theoretical Issues in Ergonomics Science and Applied Ergonomics*. A look at the abstracts of studies published at ICEE 2019 reveals a large concentration of research focused on issues related to the impacts of the temperature on people, perception of thermal comfort, physiological issues based on air quality, and exposure to heat, thus emphasizing the approach of each variable and situation.

Fross, Winnicka-Jaslowska, Guminska, Masly, and Sitek (2015) consider that Ergonomics is present in all projects. They argue that the goal of each architect should be the optimization and efficiency of the project in proposing solutions and the formulation of the correct diagnosis to contemplate the needs of users in all aspects, highlighting the use of qualitative research when evaluating quality. The authors note that quality must be of a technical, functional, organizational, behavioral, and economic nature and based on the combination of tools such as observation, research, interviews, and user participation. Parsons (2000) identifies four main methods for assessing the response to environments: subjective methods, which obtain responses from users about the environment; objective methods, which focus primarily on measurements of the occupants' responses (body temperature, hearing ability, task performance); behavioral methods, which observe the user analytically; and modeling methods.

Hugine, Guerlain and Hedge (2012) present a study that assessed to optimize the working environment of radiologists. Although they do not establish a specific methodology in terms of an order of approach or steps to be followed, the authors adopt the verification of variables used to identify physical discomfort, the adequacy of the workplace, the users' perception regarding the comfort of the chairs, the workspace, and other features. In this study, the comprehensive character of ergonomic analysis can be identified.

In recent studies, the User Experience (UX) approach has also been incorporated into studies of environments by ergonomic researchers. The evaluation of the experience of the user can be carried out in different contexts and operated by different techniques involving the participation or simple observation of the users. It finds a basis in methods to assess and project the user's perception when seeking to achieve objectives of satisfaction, pleasure, and well-being associated with the success of the task. The term User Experience Design was coined by Donald Norman, in 1999 (Hassenzahl and Tractinsky, 2006), when he worked at Apple. UX stands for a holistic and integrated view of the user's experience and is strongly related to the principles of usability. In this sense, it suits for understanding users' behavior in spaces, whether urban or indoor, in the search for important data on people's activities, needs, and desires. For Bevan (2009), the concepts of the user's experience include their emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors, and achievements, which occur before, during, and after use.

It is opportune to point out that Brazilian methodologies use the same tools mentioned and adopted in international studies. However, they are included in methodological steps organized in stages that establish methods aiming to facilitate their understanding and application. MEAC (Ergonomic Methodology for the Built Environment) emphasizes that any tools can be used during their various phases. Walkthroughs, questionnaires, interviews, focus groups, systematic and unsystematic observations, filming, photographs, measurements of environmental comfort with specific instruments, techniques of environmental perception

such as mental maps, constellation of attributes, wish poem, or other tools that can be adopted to contribute to the achievement of the objectives of the analyses.

It is also important to emphasize that works about design processes prioritizing Ergonomics have also been developed, in which the ergonomic design methodology of Attaianese and Duca (2012) stands out. Sarmento (2017) points out that this methodology essentially involves users and uses the international standard ISO 13407/1999, which determines the design of systems centered on users, with a clear understanding of their characterization and of all the tasks that imply to the functioning of the activity system.

3 Applying the methodologies

This comparative study between three methodologies of ergonomic analysis aims to explain the use of these assessment tools in built environments and compare the results obtained. In order to demonstrate its use, applications were simulated in environments with similar characteristics of use and which intends to perform interventions in spaces. Before starting to explain the applied methodologies, some important considerations need to be raised. Although widely found in the specialized literature, the application of these methodological structures dedicated to the performance of human activities did not have naturally this purpose. Ergonomic analysis methodologies were originally intended to assess work situations. However, the adaptations and adjustments for their use in environmental studies have shown good results. Towards this end, simulated ergonomic analyses intended to verify the conditions of use of the environment, carry out the evaluation according to each methodology, and, based on recommendations, substantiate the renovation project of the physical environment to generate design solutions that might improve the working environment to users and activities.

As a methodological tool, for each environment, a differentiated systemic approach was used to assess the factors involved in human activities: the Macro Ergonomic Analysis methodology - AMT (Guimarães, 2010), the approach of the Human-Task-Machine System - HTMS (Moraes and Mont 'Alvão, 2007), and the Ergonomic Methodology for the Built Environment - MEAC (Villarouco, 2008; 2009).

3.1 Macroergonomic Analysis - AMT (in Portuguese)

The Macroergonomic Analysis methodology - AMT (Guimarães, 2010) is a method of ergonomic action with a participatory approach that focuses on the human being, work process, organization, environment, and machine as parts of an ample system. In this method, workers are involved in decisions about their work and activities and encouraged to make decisions at the organizational level, involving themselves in topics originally restricted to the levels of the business organization. AMT proposes using tools such as interviews and questionnaires to identify items of ergonomic demand, involving the needs in the work environment, as well as statistical analysis and decision instruments for the prioritization of the items presented in the interviews and questionnaires. The implement of AMT follows six stages: project launch, assessment, diagnosis, design, implementation and evaluation, and validation.

3.1.1 Step 1: Launch of the project

This comprises an initial survey of needs, with the participation of the users of the environment, when workers are involved in assessing the use of space.

3.1.2 Step 2: Appraisal

Initially, an indirect observation is made with photographic records of work activities. Unstructured interviews are conducted with users, who talk freely about their work, reporting, in order of priority, the functional aspects related to environmental, organizational, interpersonal, and other issues relevant for them. Based on the discussion of the data obtained, it follows a prioritization of the problems for investigation and definition of the intervention schedule.

3.1.3 Step 3: Diagnosis

Interview responses are tabulated with staggered numerical values according to the order of citation. The items with the highest score are considered priority ergonomic demands, which can be categorized, for example, in the environment, biomechanics, work organization, and risk of the work. Regarding the environment category, the demands can be: furniture without enough space, the inefficient layout of the environment, excessive noise, and insufficient lighting. In relation to the biomechanical category, the items result from injuries complaints, possibly caused by postures of the body on inappropriate furniture, and also by stress due to the fatiguing nature of the service. As for the organization of work, observations are made on working hours that are excessive, centralization of the service, insufficient number of workers, and demands

not solved by the administration. Regarding work risks, it comprises situations that involve risk in the performance of the job, such as the aggressiveness of the public that frequents the site.

3.1.4 Step 4: Designing blueprints

In order to draw up solutions, the issues prioritized in the diagnosis start to support the blueprint. Ergonomic actions would serve as guidelines to guide the architectural design, such as standardizing work environments, dimensioning workstations, designing internal signage, renovating cooling and lighting systems, and implementing acoustic resources.

3.1.5 Step 5: Implementation and evaluation

Bearing in mind that the purpose of the ergonomic evaluation would be to develop an architectonic design for the built environment, the information collected will be translated into ergonomic actions that target the architectonic space. The other demands must be presented to the directors of the company to generate a set of actions to strengthen the changes in the physical work environment. The architectural blueprint implemented should be discussed with the managers and users to verify if the solutions have met the demands efficiently.

3.1.6 Step 6: Validation

After evaluating the results achieved, a final report giving full details of the blueprint is issued (Guimarães, 1999).

3.2 HTMS Analysis

The Human-Task-Machine System - HTMS (Moraes and Mont'alvão, 2007) focuses on human interaction with equipment, machines, and environments. The use of this approach enables the recognition of the problem and understanding of the system, leading to an ergonomic diagnosis with recommendations. The intervention is divided into five stages: assessment, diagnosis, design, validation, and ergonomic detailing. In the present study, the methodology was applied up to the phase of blueprint design.

3.2.1 Step 1: Ergonomic appraisal

The ergonomic appraisal encompasses the conduction of the mapping and delimitation of physical, environmental, movement, and informational ergonomic problems, with on-site observations and structured interviews with users. Problems are ranked based on the human costs of the work.

3.2.2 Step 2: Ergonomic diagnosis

The ergonomic diagnosis involves systematic observations of task activities in real work situations. The problems to be identified could be categorized into: uncomfortable workplaces with no space to adequately accommodate equipment or to store material for personal use. The physical-environmental analysis verifies the noise levels and the illuminance according to the regulatory standards. It is verified whether the layout of services and the distribution of furniture follow the flowchart of the service and if there is a need for internal signage. Ergonomic demands could be identified as: high ambient noise, lack of signage, insufficient space, lack of space organization, insufficient work area for handling and siting equipment, and lack of a place to store personal items.

The table below shows an example of a summary of an ergonomic audit report obtained by applying an HTMS to a built environment. A table indicating the problems reflects the taxonomy found in the problematization of the system. Each problem must be analyzed in-depth, thereby identifying the variables linked to it.

	Interfacial	Indoor Spatial/ Architectural	Accident Risks	Accessibility
Class of Problems	· TV in the social area outside the residents' angle of vision	· Lack of space and the arrangement of furniture hinders daily activities	· The child's bed is under the window	· Restricted access to the window prevents the area being cleaned and used
Requirements	· Place the equipment in the users' immediate field of vision	· Architectural design that should take into account all users' needs and restrictions	· Reposition the bed	· Promote access
Task constraint	· Discomfort caused by inappropriate postures taken up	· Difficulty in moving around and gaining access to furniture · Inadequate movements and postures	· Exposure of the child to danger	· Inadequate postures · Flexion of the back and extension of the arms.
Human costs	· Fatigue in the spine and neck · Physical discomfort	· Generalized muscle pain · Trauma. · Anxiety · Stress · Loss of balance	· Loss of balance · Death	· Expenditure of great effort to carry out the tasks Expenditure of great effort to carry out the tasks · Muscular strain
System dysfunction	· Interruption of activity · Improvisations: use of cushions	·Accidents · Difficulty in performing the task · Unviability of accesses · Physical discomfort	· Imminent risk of falls	· Difficulty of access and cleaning · Poorly performed tasks
Suggestions	· New physical arrangement · Support for the TV to rotate	· Ergonomic architectural design · New physical arrangement	· New physical arrangement · Protection net	· New physical arrangement · Design of architecture of the interiors
Restrictions	· Financial resources · Non-consideration of the problem	Financial resources · Neglect of architectural design · Permissiveness of the city building code	·non-consideration of the safety problem	·Non-consideration of the problem

Table 2: Formulation of problems in HTMS: Adapted from Costa *et al.,* 2003.

3.2.3 Step 3: Ergonomic design of blueprints

The ergonomic design of blueprints aims to adjust the space according to the demands of the users, both in physical aspects and their perception about these spaces thought a renovation project of the space. Therefore, the requirements for the project are the distribution of the environments based on the internal flow chart, according to the various procedural steps to avoid the crossing of antagonistic flows; application of measures to restrict environmental noise; contemplation of resources to organize the internal space; inclusion of an internal signage project to meet the information and orientation needs for the environment.

3.3 MEAC Analysis

The Ergonomic Methodology for the Built Environment - MEAC (Villarouco, 2008, 2009) analyzes the physical space based on a systemic approach, covering variables of the areas involved in the built space and having the user of this space and his/her environmental perceptions as a primary element since this is the element that absorbs the impacts that the environment transmits. MEAC consists of four analytical steps: Global analysis of the environment, Identifying the environmental configuration, Assessing the environment in use in the performance of activities, and Perception of the environment. The analysis is followed by the Ergonomic Diagnosis of the environment and concluded with Propositions. The table below briefly presents the steps for applying MEAC and the objective of each one.

MEAC - Metodologia Ergonômica para o Ambiente Construído MEAC - in English, Ergonomic Methodology for the Built Environment		
Step		**Objective**
Phase I	Global analysis of the environment	Observe information about the organizational structure, the dynamics of the institution and the work processes, the spaces and their characteristics, general conditions of the environment.
	Identification of the environmental configuration	Identify all physical and environmental conditioning factors, cladding materials, accessibility, measurements of comfort, comparison with legislation, survey of layout.
		Obtain information of a physical order and organizational information, as well as a description of prescribed tasks.
	Evaluation of the environment in use	Identify the suitability of the environment, (to what extent it facilitates or hinders the development of activities) by analyzing the flows and spaces for the conduct of tasks.
Phase II	Perception of the environment	Identify the users' wishes in relation to the environment surveyed, by using Environmental Psychology tools
Diagnosis	Ergonomic recommendations	

Table 3: Structure for applying MEAC. Source: Sarmento (2017) adapted from Villarouco (2011).

Among the methodologies dealt with in this paper, MEAC is the example conceived to the approach built environments since its beginning. It arises from the need to define a tool that systematizes the ergonomic observation of the space in which people develop activities, regardless of whether they are formal work activities, domestic, educational, or even leisure activities.

3.3.1 Step 1: Global Analysis of the environment

The phase of the overall analysis of the environment contemplates the collection of information about the environment and activities. First impressions are taken in an attempt to understand the environment and its main characteristics. A walkthrough or Accompanied Tour is usually used, during which the necessary information is collected from the appropriate person who has the necessary data. When applied in an environment, it can help to identify some problems, such as: the irregular ambient temperature, deficient internal signaling, exposed electrical wiring, and lack of delimitation of environments that require different procedures.

3.3.2 Step 2: Identification of the environmental configuration

In the identification phase of the environmental configuration, the physical and environmental conditions are verified using the survey of the environment data, such as: dimensioning, lighting, ventilation, noise, temperature, flows, layout and accessibility conditions, formulating the first hypotheses about the question of the influences of space on carrying out work activities. Using the layout plan, the internal distribution is verified, which enables a check to be made on the workspace, and if the grouping of the workstations adversely affects the performance of the activities, either because of sound interference or because of the loss of privacy, which causes embarrassment due to personal space being invaded (Hall, 1982). Lighting conditions, temperature, and noise level are also evaluated according to the values recommended by Brazilian standards that regulate environmental comfort.

3.3.3 Step 3: Evaluation of the environment in use during the performance of activities

The step of assessing the environment in use during the performance of activities aims to identify how facilitating or inhibiting the environment is revealed when the activities it houses are being undertaken. It encompasses the concepts of activity space (Boueri Filho, 2008); anthropometric models to assess circulation (Panero and Zelnick, 1996); and structured observation as the most used technique, along with photographs and film footage. At this stage, circulation flows, lack of circulation space, and movement impairment can be verified.

3.3.4 Step 4: Environment perception of the user

In the Environmental Perception phase, cognitive variables are identified, thus verifying the user's perception of the environment. Several tools can be adopted, such as: the Constellation of Attributes, the Wish Poem, Mind and Cognitive Maps, and a Behavioral Map. A list of wishes and/or findings, depending on the tool

adopted, is obtained, which represents what the user has expressed. As to adopting the Constellation of Attributes (Schmidt, 1974), the users' responses in relation to the ideal environment can refer to a comfortable, pleasant, spacious environment, with a good internal distribution, with good thermal and lighting conditions, and with appropriate furniture. Responses regarding the environment that users occupy today may reveal that they consider the environment to be inadequate, noisy, and poorly distributed internally. The conjunction of users' responses to the two different situations may reveal the perception that the environment in which they work is not suitable for carrying out their activities, thus indicating which demands are a priority for them, such as improving internal distribution, interventions in environmental conditions and the suitability of furniture.

3.3.5 Step 5: Ergonomic Diagnosis of the environment

In the ergonomic diagnosis, a general understanding of the situation is obtained, thereby generating data for the phase of proposing interventions and solutions of the issues that negatively interfere in the performance of the system. The data obtained in the first and second phases are compiled, analyzed, and compared, thus generating the diagnosis, formed by the conjunction of the vision of the expert researcher with that of the lay user who experiences the situation. Demands can be identified as inadequate distribution of environments, conflicting flows of movement of people and services, lack of internal signage, workstations with inadequate dimensions and configurations, and lack of compliance with regulatory standards for the physical conditions of the environment.

3.3.6 Step 6: Ergonomic propositions

The final product of ergonomic analysis are propositions, expressed in a list of recommendations for the project in order to solve the problems identified. These may deal with correcting cooling and lighting systems in order to provide adequate environmental conditions, dimensioning workstations to accommodate users and their work materials, redistributing workstations, or grouping similar services, so that there is no crossing of flows.

4 Results

From the aspects addressed in each analysis and the final product of the evaluation, a summary table was created with the tools used in the three evaluations, in order to identify the characteristics of each methodology. From the results of the interventions, it is concluded that the focus of each methodology directs the type of analysis to be performed in the environment. Macroergonomic analysis aims to address hierarchical management levels, communication, and the organization of work. The HTMS analysis addresses the detailed study of activities performed in a real work situation. MEAC delves into the physical and functional data of the environment, which are added to the perceptual aspects of the users. All methodologies propose the use of interviews or other tools with users, in order to collect information about them, their desires, and impressions about the environment.

Methodology / Tool	Macroergonomics	SHTM	MEAC
Purpose of the methodology	Deals with the levels.	Tackles the study.	Goes into the data in depth
User's expression about the environment	Free interviews with users about their impressions of the work environment in general.	Structured questionnaires.	Guided tour by the users in the environment and interview on the impressions on the environment
Addressing the physical aspects of the environment	The physical aspects are related in accordance with the users' impressions.	Analysis using measuring instruments.	Survey of the data using measuring instruments and representation in drawing.
Addressing the functional aspects of the environment	The functional aspects are related in accordance with the users' impressions.	Systematic observations of the activities of the task in real work situations.	A check is made on the conditioning flows, layout and influence on the conduct of the activities of the work by means of systematic observations.
Survey of demands	From data collected in the unstructured interviews.	On-site observations, interviews and photographic records.	Conjugation of surveys performed with instruments, systematic observations and users' perceptions.
Categorization of demands	Environment, Biomechanics, Company, Organization of the work, Risk of the work and clients.	Physical, environmental, movement and informational demands	Environmental configuration, environment in use and user's perception of the environment.
Prioritizing demands	The answers most cited in the interviews indicate the factors that most affect users.	Participatory system of user and technicians to quantify and objectify the evaluation of alternatives.	Conjugation between the analyses of the physical environment and the users' perceptions.
Elements generated for drawing up the built environment project.	The information collected is translated into ergonomic actions directed to the architectonic space.	The requirements for carrying out the task determined in the ergonomic diagnosis conceptualize the project, considering the allocation of functions between man and the environment.	The general understanding of the situation generates data for the propositions of interventions, to adapt the environment to the type of activity performed in it.

Table 4: Aspects tackled in the ergonomic analyses. Source: The authors, 2020.

Demands are prioritized based on the answers most cited in the interviews, which indicate the factors that most affect users in the Macroergonomic analysis. In the HTMS analysis, the participatory user system and techniques are used to quantify and objectify the evaluation of alternatives. In the MEAC analysis, the responses of the interviews with the users show the perception and the desires, which, combined with the analysis of the environment, highlight the most pressing demands.

The elements generated for drawing up the design blueprint of the environment, in the Macroergonomic analysis, originate from the information collected, which is translated into ergonomic actions that target the architectonic space. In the HTMS analysis, the requirements for carrying out the task, determined in ergonomic diagnosis, conceptualize the project, and take into account the allocation of functions between the human being and the environment. In the MEAC analysis, the general understanding of the situation, obtained from combining the elements collected in the analyses and the impressions of the users, generates data for the intervention

5 Discussion

The focus of each methodology studied proved to be an indicator of the method to be used in an ergonomic analysis, depending on the type of results expected from the study, and also on the instruments to be used. However, it is observed that some elements are complementary in the analyses, based on the aspects revealed during the study. Thus, it should be borne in mind that the way of approaching the object of study is determined by the researcher's intentions: if the analysis is intended for interventions at managerial and work organization levels, the analysis to be used could be macro-economic; if the analysis is intended to verify activities performed in a real work situation, the analysis to be used may be the HTMS; or if the analysis is intended to focus on the physical and functional data of the environment, evaluated in real work situations, the analysis to be used could be MEAC.

The ergonomic approach aimed at identifying the performance variables of the physical environment derives from the approach adopted by the methodology used in its evaluation. Although they are different

methodologies, each with its own scope, specificities that must be selected according to the type of use, all of them preserve, in essence, the systemic character of Ergonomics and the main focus on human beings. Thus, they find an echo in the work of Hugine, Guerlain, and Hedge (2012), which also addresses several variables that make up the environment of activities, analyzed from interactions with users. The methodologies explored in this article are still in line with the recent introduction of UX (User Experience) into ergonomic studies of environments. The systemic and global view of Ergonomics on the situations of development of human activities, including environments, are in line with the concepts of UX, which argues for a holistic and integrated view of the user's experience.

Here, the studies by Parsons (2000) are also brought back into view, which, being more aligned with those published in the last International Conference on Environmental Ergonomics (ICEE), held in 2019, focus on the consequences of thermal, acoustic or luminous variables on the human being, and their adverse effects on activities and health. Although they do not explore the integral character of Ergonomics, they present the human element as a central object of research. The opportunity to use three different methodologies in similar work environments contributed to the discussion on working methods, thus optimizing the work of analyzing the built environment with considerations on forms of approaches, a survey of demands and generation of elements in order to draw up a physical intervention project in the environment.

What methodology to use in a future ergonomic analysis? The answer could be the tool that unveils the most relevant aspects for the analysis, or the one that is most suited to the particularities of what we want to emphasize in the study of the environment. However, it is up to each researcher to choose the methodology that best suits the purposes of their investigation.

6 Conclusion

This paper sought to dialogue with the theme "Questions of method" by addressing the adoption of ergonomics methodologies applied to built environments and incorporating it into the proposed discussion for this edition of the magazine. The starting point was to identify elements that support the definition of the methodology to be adopted when evaluating built environments, from an ergonomic perspective. It was sought, therefore, to achieve the objective of identifying differences or similarities between ergonomic analyses of environments, conducted from different methodologies, and setting criteria of applicability. The development of the text produces answers to the initial question, as well as reaching the proposed objective, presents three methodologies, each of which is described in detail, and the results achieved in the applications are compared. Although the entire study was carried out using three methodologies developed by Brazilian researchers, the text addresses their alignment and relevance with reference to international studies developed in the area.

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