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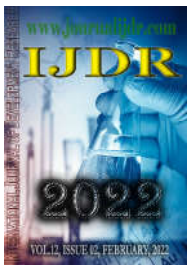

RESEARCH ARTICLE OPEN ACCESS

APPLICATION OF ERGONOMIC WORK ANALYSIS IN AUTOMOTIVE INDUSTRY PROCESSES USING COMPUTATIONAL INTELLIGENCE FOR DECISION MAKING

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ABSTRACT

Ergonomics have proved to be increasingly important for industrial processes around the world. The evolution of machinery and equipment has caused several disorders in occupational health at work. Therefore, it is extremely important to make a comprehensive reading of the workstations and ergonomic analysis tools. The objective of the article is to make an application of the technological resources of fuzzy logic in the results found in the Ergonomic Analysis of Work (AET) in seven jobs in the automotive industry of the Industrial Pole of Manaus (PIM). The methodology applied is based on the application of ergonomic tools using Suzanne Rodgers`method and on the mathematical models characterized by Fuzzy Inference for decision making on various disorders that occur with the health of the employee. The results found in the ergonomic tool ''Suzanne Rodgers'' applied to the movement of upper and lower limbs and other observations in the productive sectors, with the application of Fuzzy Logic, it was shown that the linguistic variables by colors, the legend that shows the classification of ergonomic risks through run. Therefore, they serve to make a comparison and discuss the importance of ergonomic processes for the benefit of the worker in the automotive industry for decision-making.

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INTRODUCTION

Ergonomics presents itself as a science for the prevention of ergonomic accidents in work activities and aims to shape these interactions in the work environment and adjustments for comfortable, efficient and safe performance in the face of the capabilities, limitations and other characteristics of each person in their activity [Karwowski, 2012]. For [Gibbs, 2005; Li, 2015]in the work activity the human being interacts in his routine with the various components of the work system such as: equipment, instruments and furniture, creating sensory, energetic, postural, cognitive and organizational interfaces, where your organism, your mind are directly interconnected to the well-being in the productive process. The lack of applicability of anErgonomic Work Analysis (AET) in a sector or activity, can cause several damages to the worker and this idea described by [Baraldi, 2006], which in the prevention point of view, tends to present problems found in the manufacture of products and that are essential to avoid unidentified waste and that are perceived when the planned assembly time is compared with the time used, often causing delays, reworks, medical leave, excess movement and inadequate posture that may cause eventual postural disturbances, leading to the removal of the worker. For [Dul, 2012] points out the technological interactions applied to companies, which are increasingly committed to developing programs and projects that contribute to the health and well-being of workers and to the development of new models, processes, products, among other ways to ensure quality in the services and products offered to customers by the company, awakening in employees a sense of quality of life and care that consequently aims to leverage safety and productivity. Ergonomics presents itself as a complex and broad science of studies and tends to include technological resources or new tools among other resources for the application of ergonomic management in a practical way [Clegg, 2000; Macleod, 1994]. Therefore, this science has three domains of specialization: physical, cognitive and organizational for the understanding of [Ferreira *et al*., 2017], the ergonomics professional must have a multidisciplinary view with different aspects and observations that help in the classification of normative measures that assist in the process of analytical research with the possibility of improvements in the reduction of risks in the work environment.Studies applied to ergonomics with the use of adequate analysis tools aimed at evaluating the movements of the upper and lower limbs and that need in-depth and adequate studies for

assertive predictions For [Lee, 1990] Fuzzy logic is an Artificial Intelligence (AI) technique been applied as a tool for analysis and decision-making in engineering and that the AET data can be perfectly applied in a fuzzy modeling, in this case, there is a degree of pertinence of each element to a certain set of values assigned to the elements of the universe set U belong to the range of real numbers from 0 to 1, making it possible to use the technique in ergonomic evaluations [Kandel, 1991; Bogachov, 2020]. The present research contributes to the collection of ergonomic data in the industrial environment, as well as its physical conditions and cognitive aspects in accordance with the specific legislation that covers the areas of ergonomics, Regulatory Standard (NR17), belonging to the Ministry of Labor and Employment (MTE) and assertive decision making, according to [Goleman, 2017] good leadership is one capable of making decisions that generate positive results for the organization and having the autonomy to make the right choice is what will define their decisions and the way in which they present themselves is sustained. your convictions, being confident, sincere with your choices.The study proposes to carry out an evaluation of the AET of the seven jobs of an automobile company and the ergonomic risks to be found by the ergonomics professional, and the risks found and other observations, can be used in the techniques of Artificial Intelligence (AI) through fuzzy logic, and the results can help the ergonomics professional for decision making and suggest improvements to the sector with preventive measures for the optimization of the work environment and quality of life of employees.

LITERATURE REVIEW

Ergonomics: Man in his essence needs a suitable work environment to produce with safety and quality, according to [Voronkova, 2018], the study of ergonomics can be defined as the science that analyzes the interactions of man with the environmental conditions related to work. and aims to improve the physical and psychological conditions of human beings at work, taking into account the ergonomic postures and movements of the workers' upper and lower limbs. Ergonomics has as its object of study the well-being of the worker in his work activities and is guided by the comprehensive knowledge of the specific characteristics of each activity or position or even the psychophysiological conditions contemplating different domains of knowledge, constituting a structural unit that allows to establish a coherence based on its methods of action with the help of several professionals establishing a multidisciplinary science [Keestra, 2017].According to [Oliveira, 2020], the AET has a fundamental role in carrying out a detailed study of the movements of the human body in the workplace and making a complete diagnosis to prevent the risks of ergonomic and work accidents and can be related to several factors such as poor posture, lack of lighting, inadequate temperature, noise levels, insufficient ventilation or inappropriately sized tools. In this way, professionals in ergonomics stand out for the specific knowledge endowed with a science mentioned by [Sun, 2019], they are able to ensure the identification, diagnosis and development of measures to solve ergonomic problems that affect health and work performance human.

To [Wilkesmann, 2018], the jobs must be planned and organized to meet the efficient production logistics and fit the proposed activities, in case a job is not suitable, they can perfectly imply a more sedentary or inadequate work, in the which both standing and sitting postures are maintained for long periods of time can cause permanent or permanent damages in the worker. By studies proposed by researchers, in which they indicate that the human body was not designed to maintain the sitting posture for long periods of time, since this causes muscle and ligament contraction of the spine, which ends up leading to a decrease in muscle activity and the consequent decrease in blood flow causing sequelae and absence from work to the worker [Behm, 2018].In the understanding of [Ning, 2021], the lack of planning of a job may be associated with some of the most common risk factors, namely musculoskeletal factors, which are often linked to the adoption of inadequate postures, poor lighting between other risks present in inappropriate spaces. For [Das, 2021], the management of a company aims to provide all workers with a job suitable for participatory production and with fewer accidents at work related to muscle and bone structure, including observations of workplaces in many areas. relevant cases: indoor air quality, noise and thermal environment, among other risks.According to[21], there are thirty-seven norms that are applied to Occupational Health and Safety (OSH) regulated by the Ministry of Labor and Social Security (MTP) that benefit and protect the worker. The Regulatory Norm17 has as a guideline for companies, the establishment of parameters that allow the adaptation of working conditions to the psychophysiological characteristics of workers, in order to provide maximum comfort, safety and efficient performance in relation to ergonomic aspects. In this way, working conditions include aspects related to lifting, transporting and unloading materials, furniture, equipment and the environmental conditions of the workplace and the organization of work itself [Vink, 2004].To evaluate the adaptation of working conditions to the psychophysiological characteristics of workers, it is up to the employer to carry out the AET, which should address, at least, working conditions, the requirements addressed in this work involve a survey of working conditions and their adjustments. For [Hendrick, 2008], other aspects must be observed and analyzed according to the worker's complaints in relation to the work environment, such as postures, cargo movements, the furniture of the workstations, equipment, environmental conditions, work organization among other aspects that can be taken into account by the Ergonomics specialist with tool applications, as shown in Figure 1.

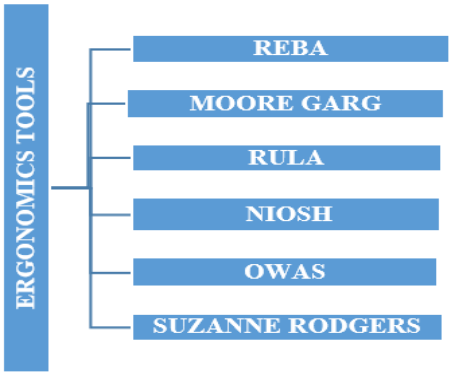


Figure 1. Ergonomic tools that can be applied in productive activities. Source: Authors, (2021)

The ergonomic tools were created to guide the professional in choosing the best methodologies and tools suitable for each type of activity. Remembering that not all activities are the same and the tool chosen is at the sole discretion of the ergonomics professional. According to [Battini, 2011], the workplace must be evaluated and analyzed on technical criteria, adopting the appropriate ergonomic methods and tools to solve the problem of each activity or business process, facilitating and streamlining its decision and analysis, pointing out the degree of criticality to which the worker is subjected when performing a certain activity, making it possible to diagnose situations that most harm the health of the worker, from lifting excessive loads, to inadequate postures and repetitive movements performed inappropriately and that need immediate corrections.

Suzanne Rodgers Method: A suitable job requires the application of tools that have a diagnosis of bodily effort (time and effort), in which a questionnaire, checklist and application of the Suzanne Rodgers methodology can be applied in the activities that are proposed in this article, proposing to the reader a better understanding of the phenomenon to be studied in order to obtain a mapping of the most requested body segments and which areas need actions for adequacy, being evaluated the frequency and posture of the worker in the work environment [Dianat, 2015]. For [Draskovic, 2020] the Suzanne Rodgers methodology has as its object of study the evaluation of the level of effort, effort time and effort per minute of the worker who is directly connected to his work activity and in which it also facilitates the evaluations and identification of tasks that present the possibility of ergonomic risk, identified simply and summarized in Table 1.

Tabela 1. Upper limb assessment methods Suzanne Rodgers

LIMBS	LOW EFFORT	MODERATE EFFORT	HEAVY EFFORT
Neck	Partially rotates	head rotates fully	Flexed head > 20%
Shoulder	Short or extended	Unsupported abductees	Application of force or weight
Body	Tilts slightly	Moderately heavy load	Force with rotation
Arms and foreamrs	Low strength (F < 1 kg)	Moderate strenght (1 < F< 2,5 Kg)	Arm loads (F > 2 Kg)
Hands fists and fingers	Low strength(F < 1 Kg)	Moderate strenght (1<F< 2 Kg)	Force (F>1Kg) sliperry surface(F > 2Kg

Source: Authors, (2021).

Fuzzy Logic: According to [Chuen-Chien, 1990], fuzzy logic was conceived by Lofti Asker Zadeh in 1965 due to his analytical observations and for presenting variables and characteristics different from knowledge about objectivity and its main purpose is to aggregate in the resolution of problems that have a characteristic of subjectivity, in which the information is called nebulous and which cannot be applied to Boolean logic, in which it has an evaluation of limited values and which has the characteristic of assuming two values, true or false [Zadeh, 1988].The professional who uses fuzzy logic techniques has the autonomy to insert a set of information in the fuzzy logic, as it allows inserting an infinity of values in the range from 0 to 1, which are called levels or degrees of pertinence, thus assuming values much more broad than merely true and false. A fuzzy inference system has as its main composition elements the fuzzifier, inference rules, inference engine and defuzzifier, in which the understanding below is clearer, described by [Chuen-Chien, 1990; Zadeh, 1998].

- **Fuzzifier:** It is the part of the fuzzy inference model responsible for converting the input data into values that can be represented in degrees of inference, having its variation between the range of 0 to 1.
- **Fuzzy Inference Rules:** It is the set of rules used in the fuzzy inference system, these rules essentially serve to make the model have a similar behavior in terms of decision making, according to the knowledge of the expert who modeled and imputed the rules in the inference system. This is an essential part for the model to have a better efficiency behavior, so to model a fuzzy system it is necessary to have an are specialist under study so that the answers are validated by it.
- **Inference Engine:** This module is responsible for unifying and performing the calculation process of the behavior of the fuzzy system that is modeled, it is worth mentioning that the values obtained from this module are numerical values.
- **Defuzzifier:** After the step in which the inference engine performed the mathematical calculations and resulted in numerical values, the defuzzifier is responsible for converting these numerical values to linguistic variables, in order to facilitate the decision-making process, using a method to carry out the process of converting numerical values, for this there are some methods in which it is possible to highlight the Centroid.

MATERIALS AND METHODS

To carry out this research, it was necessary to use the database of an AET held in July 2021on the company's premises, the data set includes the production of Toyota model radios evaluated in seven jobs. In which the applicability of the relevant legislation in relation to the application of the Norms were observed in the work stations. The observations started in the sense of evaluating the movements of upper and lower limbs through NR 17, which are described in the sequences below and in addition to the pertinent observations. The results aim to answer if the ergonomic conditions in the work environment influence the health, comfort and safety of the worker in a continuous production rhythm of car radios.

Materials

The materials used for the development of this work were Matlab® 2016 and the Ergonomic Work Analysis (AET) report of the year 2021.

Matlab® 2016 was used to support the implementation of the fuzzy inference system, through the toolbox available in software. In relation to AET, it was used as a basis for the development of the fuzzy inference system, in order to imitate the behavior of the specialist.

Methods

The methodology is applied to activities that start at 7:05 am to 5:15 pm from Monday to Thursday and on Friday from 7:05 am to 3:15 pm with breaks of 60 minutes in the morning and 60 minutes in the afternoon and 60 minutes of lunch break with breaks to meet the worker's physiological situations with a production cycle of approximately 100 seconds for the production of 300 sets per hour. To obtain a better understanding of this phenomenon, a qualitative-quantitative study will be necessary, as it is characterized by the use of measuring equipment, AET Suzanne Rodgers, questionnaires and the technique of AI Fuzzy Logic. Starting from a descriptive approach, the study was subdivided into parts that begin with a form of questions about ergonomic risks containing the description of the task, main aspects of difficulties mentioned by employees. The second part presents the Thomas E. Bernard

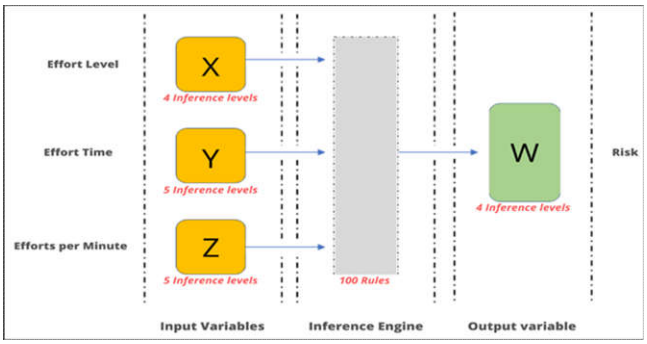
Model Design: For a better understanding of the study, it will be necessary to obtain data from the AET and include the values in input variables, inference engine and output variables in the fuzzy model and which will be presented:

Input Variables: The input variables were selected from the observed model Suzane Rodgers, in which the input variables “Level of Effort”, “Time of Effort” and “Efforts per Minute” were obtained. The variable “Level of Effort” has 4 levels of inference, namely “Null”, “Low”, “Moderate” and “Heavy”. In which the intervals will be defined in order to follow the Suzane Rodgers model.The variable “Time of Effort” has 5 levels of inference, which are called: “Null”, “Little”, “Medium”, “A lot” and “Too much”.For the variable “Efforts per Minute” it will have 5 levels, in which they were called: “Null”, “Very Little”, “Little”, “Reasonable” and “Very”.Inference Engine: In the inference engine, the rules to be used in the fuzzy inference model will be added, as will be used in the variables "Level of Effort", "Effort Time" and "Efforts per Minute", 4, 5 and 5 levels of inferences respectively, the number of rules to be used will be 100, due to this being the number of possibilities of rules for the configurations of the inference system presented in Figure 5.Output Variable: This variable will be used as a result to be shown by the system, which will have 4 possible answers, namely: “Green”, “Yellow”, “Red” and “Violet”. In which green is recommended, yellow means a warning alert, red high risk and violet equates to very high risk.After entering the data, the model applied after obtaining the AET data will be applied in the model developed in Figure 2, in which the structure of the fuzzy inference model to be implemented can be observed.

RESULTS AND DISCUSSION

Description of tasks and activit: For a better understanding to be approached on the subject, it will be necessary to describe the production process below so that we can start the AET that originated, from the need to comply with Regulatory Norm 17 and also in the search for the company to carry out a technical survey and the results to be discussed in search of improvements in general working conditions and workers.In this sense, it is necessary to

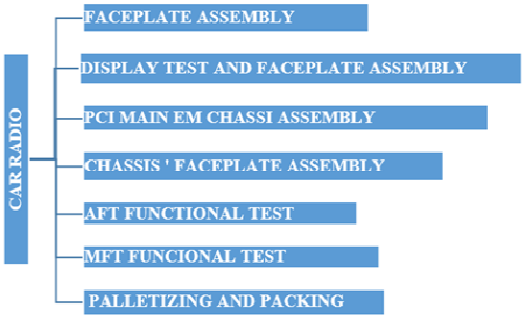
present and analyze the activities with the respective sequential images showing the processes, referring to the execution of procedures performed by the worker for a complete cycle of operation, demonstrating the main gestures, postures, reasoning, efforts etc., employees to perform the tasks prescribed in the work instructions, in order to highlight possible inadequacies if there is a mismatch between what is required by the company and what is actually performed by the worker and what strategies are used, in order to provide subsidies for recommendations for improvement.



Source: Authors, (2021).

Figure 2. Structure of the fuzzy model (Model design)

It is also necessary to evaluate the biomechanical conditions through an analysis of repeatability, force quantification, presence of mechanical compression, inadequate postures, vibrating sources, load movement, standing and sitting work. Observing aspects of work organization, analysis of working hours, periods of breaks and micro-breaks, meeting personal needs outside of scheduled stops, production system, setting goals and deadlines.It is proposed to observe, through an analytical study, the quality of the analyzes performed in the seven points described in Figure 3, including the handle, location, conservation, operating condition, vibration emission, force level, existence of sharp edges, weight, rocker, models of pliers, scissors, buttons and buttonholes, cranks, levers, JIGs, screwdrivers, workbench, including an interview with the worker that were carried out at the work place in order to create involvement and raise possible complaints, difficulties , observations, etc.



Source: Authors, (2021).

Figure 3. Flowchart of the production of the toyota vehicular radio

Evaluation of Station 1 - Faceplate Assembly: A good job evaluation becomes essential for a good analysis of the activities that will be reported in this chapter, in which we can present a production process of a Toyota model device. It was observed, the productive environment and the actions in which workers will be analyzed with the respective sequential images referring to the procedures carried out by the worker for a complete cycle of operation, demonstrating the main gestures, postures, reasoning, efforts.The biomechanical conditions of the worker were also observed, analyzing the repetitiveness, quantification of force, presence of mechanical compression, inadequate postures, vibrating sources, load handling, standing and sitting work and also aspects of work organization, journey analysis of work, periods of breaks and micro-breaks, assistance to personal needs outside the programmed stops, production system and legislation. Each workstation has a peculiar characteristic and the worker in this process is responsible for assembling the faceplate that will compose the device produced by the Toyota model company. The LCD, PCI and front frame assemblies are made using the JIG worker for assembly, screwing and inspection by camera in box. The worker's activities described in Post 1, as indicated in Figure 4 onwards, consist of picking up an ivory faceplate, placing it in a JIG, picking up LCD and PCI, assembling a faceplate, scanning a subassembly, connecting flat cables, performing bolting and visual inspection, transferring the material to the next station.In this position, it is shown in Figure 4 A, the identification of the worker standing making preparations for the beginning of the work cycle by picking up the ivory faceplate in front of him, performing the right arm flexion, since the reach area, as Figure 4A and Figure 4B, is a little distant from the worker, showing a mismatch and, according to the interviewee's testimony, its activity is considered light, as it removes the plastic packaging from the faceplate and discards it in a suction system in front of it, performing flexion of left arm, also with light effort.

Source: Authors, (2021).

Figure 4. Overview of sequenced activities performed in production

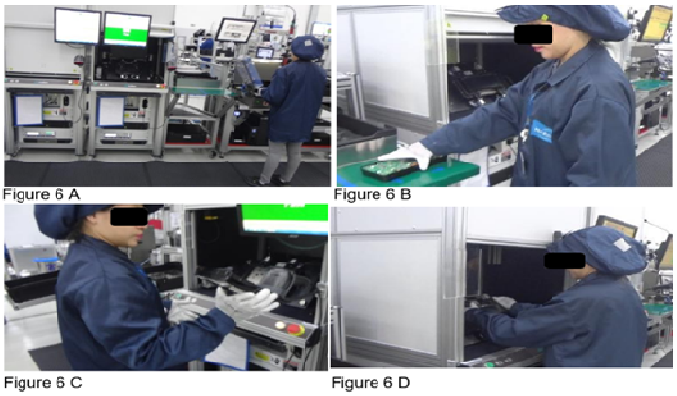
The activities of this process begin by scanning the part, as shown in Figure 4 C, the effort to activate the scanner is considered light, as well as the laser reader works correctly and the software easily identifies the part. In Figure 4 D, the movements and demonstrations of postures at the workstation were observed, in which, with the right and left hands, fitting the microphone to the faceplate, pinching the right thumb and index fingers, performing slight hyperflexion. of the wrist with fittings and light efforts.At the end of the initial faceplate assembly process, the worker releases the assembly and bolting JIG by pressing the button on the JIG on her left side, while her right hand pushes the JIG over rails to be inspected by a camera box in front of her with light movements. , starts to observe the monitor in front of him, waiting for the software release process that allows the approval of the assembly.In the following process, the worker takes the LCD, which is in ivory on a mat on the left side, performing arm flexion and abduction, in addition to pinching the fingers of the hand, with light effort. When fitting the two pieces together, holding the display holder over the LCD, fixing the two parts in pulp gripping movements. The worker informs that from her point of view and experience of the activities, fitting requires low physical effort and that more skill than strength will be needed, as shown in Figure 5 A.

Source: Authors, (2021)

Figure 5. Faceplate assembly and inspection process

In this process, it is necessary to place the subset on the faceplate in an assembly JIG, applying light pressure with the hands that identified pulp grip. In view of this process, it was observed that the hands and wrists are in a position close to neutral, the worker takes the ivory PCI on her left side, performing arm flexion and trunk lateralization, as the reach area is low in relation to her bodily limitations.In the assembly of connectors and accessories (microphone, flat cables and interconnection of components) it is necessary to confirm the adjustments by pinching the fingers and hands with the aid of artificial lighting, coming from individual luminaires on the assembly JIG is sufficient and does not cause reflectance, facilitating connections, as shown in Figure 5 C, performing palm grip and shoulder rotation movements while reaching for the screwdriver with the right hand, starting a sequence of two screws, for the perfect fit of all the components and following with the palm grip and right forearm flexion.It is important to point out that the screwdriver has a mechanical arm system that eliminates the effort of screwing and weight of the equipment, being only necessary that the worker directs to the place and starts the screwing, the worker opens the cover of the JIG and pushes, through a rail, to the box where the camera captures the image of the assembly JIG and analyzes the visualization procedures, while viewing the result on a monitor in front of you.After approval of the system, the worker returns with the JIG in its original position and removes the already assembled faceplate, performing a visual inspection and taking the LCD protection film, gluing the protection film, which was removed at the beginning of the faceplate assembly. and ends the work cycle by positioning the ready and inspected faceplate on the bench to its right, so that the worker at the next station has easy access.

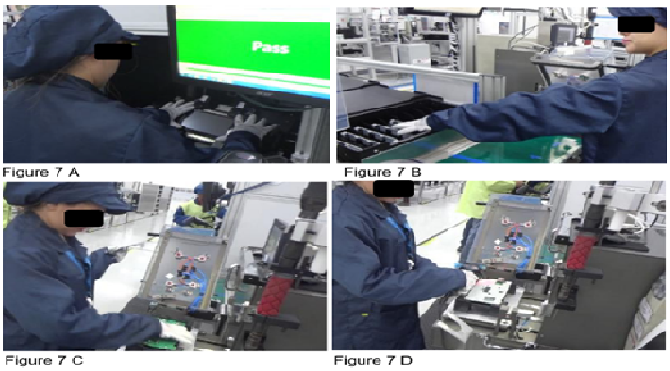
Evaluation of Station 2 - Display Test and Faceplate Assembly: The assembly cycle of this process begins when the worker of this station makes the necessary analyzes of the plates and accessories and becomes responsible for carrying out the test of the display and assembly of the frontplate of the device produced after observations on the faceplate assembled at the previous station, does the test in cabin with JIG, in an automated way.After the test, which lasts about 2:40 min, the worker assembles the frontalplate, using screws. The activities consist of picking up the faceplate, placing it in a test JIG, monitoring the test on the monitor, removing the faceplate, taking the frontalplate and screwing it into the JIG, placing it in ivory, as shown in Figure 6.



Source: Authors, (2021).

Figure 6. Overview of the faceplate display and assembly test activities

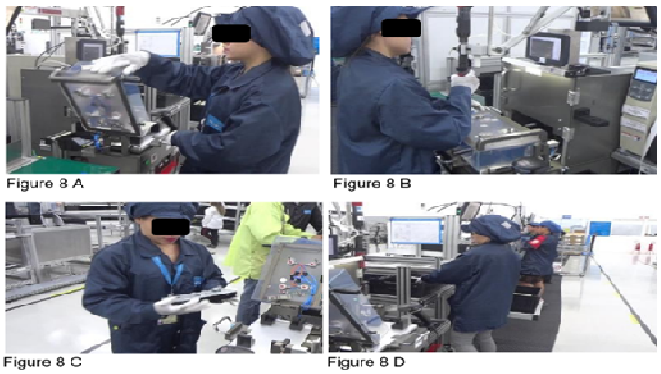
The work process begins when the worker takes the faceplate mounted in the previous station on the bench next to his work station, removing the protective film from the LCD and positioning it on a support in the test JIG, scanning the part in a fixed scanner. next to the test JIG, which is in position for readability. The worker performs a push-up to reach the JIG, which is positioned close to the front edge of the cabin. In this way, 2 cabins are available that perform the same tests, but at a different programmed time so that one device is released at a time, considering the assembly period that is carried out after the test.In this workstation, the JIG has sensors that identify the part and mechanically fix the faceplate for the test. The worker only needs to position and wait for the device to close, as the JIG is sized for the model, not causing difficulties in placement, as shown in Figure 7 A.



Source: Authors, (2021).

Figure 7. Activities and analysis in placing frontalplate on faceplate

At this station, it is necessary for the worker to carry out tests by scanning, using the buttonhole at the base of the cabin. pressing the start of command activation, of the JIG with the function of closing the access door and automatically starting the tests and at the end of the part scanning, performing accentuated arm flexion.The entire test system is automated, the monitors present the status of each cabin, presenting the tested, approved and failed items in different colors and easy to understand for workers. After carrying out the requested tests, the screen displays the word PASS on a green background, as shown in Figure 7 A, in this way, the product will be validated for later approval of the process. The test lasts between 1:40 min and 2:40 min, precisely to compensate for the assembly time, releasing one device at a time to the worker.After approval of the test, the cabin opens the access door to the JIG, the worker removes the faceplate in pulp grip and continues walking a few steps to the assembly bench, where he takes the ivory frontplate at his side, performing flexion with the left arm, as it is a little distant from the worker, providing a displacement of limbs and can be reviewed by the company, as shown in Figure 7 B.Then, the placement of the faceplate in the assembly JIG was observed with the right hand while the left hand holds the frontalplate, as shown in Figure 7C. At this moment, the scanner reads the identification tag of the faceplate that is being assembled, placing the frontalplate on the faceplate in an assembly JIG, performing pulp gripping with low effort, requiring more skill, taking the tag in the printer in front of you , pinching the fingers, as the reach area is a little far from you, sticking the label on the frontplate and scanning the part again, as shown in Figure 7 D in sequence with screwing in Figure 8.



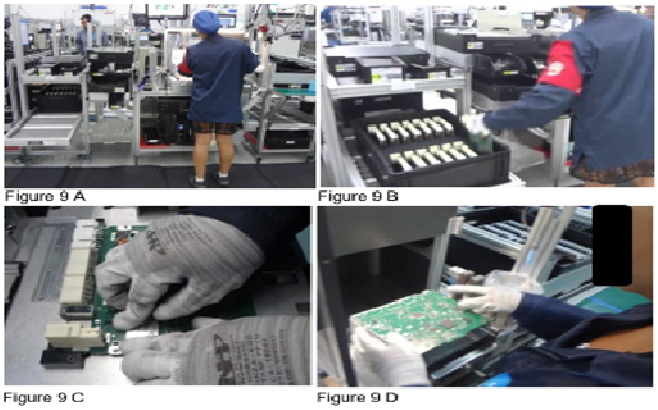
Source: Authors, (2021).

Figure 8. Bolting activities and analysis and process views

The process consists of performing the screwing, as shown in Figure 8 A, it was observed that the worker needs to lower the cover of the assembly JIG and perform the screwing, through palm grip and adduction of the right arm, taking the screwdriver with the right hand and in Figure 8 B, starting a sequence of 4 screws, performing palmar grip and flexion of the right forearm with downward movements and pressure, finishing the desired torque.

After completing the screwing, observations and adjustments were made for later reading and approval by scanning, the worker removes the faceplate and the assembly JIG, performing pulp gripping, performing the visual inspection, as shown in Figure 8 C. After inspection, the faceplate will be removed by the line feeder and made available to the radio assembly station (chassis + faceplate), as indicated in Figure 8 D.

Assessment of Post 3 - Mounting the PCI main in the chassis: At this station, it is necessary to apply thermal paste and screw the device, assembling the heatsink using the device with a mechanized arm, which is placed on the chassis and made available to the worker at the next station, as shown in Figure 9 A. The activities consist of picking up PCI and applying thermal paste, assembling and applying thermal paste in heatsink, assembling a subset in PCI, placing it in the chassis, performing arm bending and palm grip, indicated in Figure 9 B, then it is positioned on the assembly JIG in front of you, pinching the fingers of the hands, taking the shield cap tuner in ivory fixed to the workbench, keeping the left arm close to the body, pinching the fingers and hands.



Source: Authors, (2021).

Figure 9. PCI assembly activities and analysis

To complete the perfect fit on the PCB, the worker needs to perform the clamping and digital compression on the board that are necessary in the operation, in which simple adjustments are needed with little resistance to the fit, the worker takes the shield cap tuner in ivory fixed to the bench, keeping the left arm close to the body, pinching the fingers of the hand, then proceeding with the engagement in the PCI, performing the pinching and digital compression, with the handle of the shielding holder in ivory in front of you, with arm flexion left near 90 degrees, as the range is a little high in relation to you, as shown in Figure 10 A.

Source: Authors, (2021).

Figure 10. Activities and analysis of accessories assembly

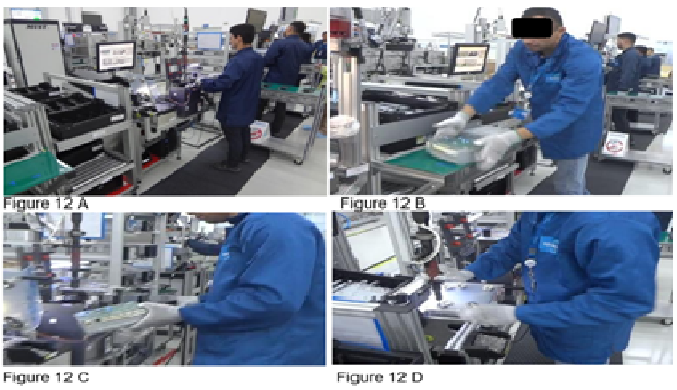
Figure 10 B, shows the process of placing the connector on the PCB, fixing it in digital compression of the thumbs and forefingers, requiring more skill in the preliminary heatsink assembly, followed by the placement of the heatsink amp, which are taken in fixed containers. next to the bench, the worker bending the arms and holding the pulp with the placement of one piece on the other, fitting them by placing the subset in JIG on the rails for the thermal paste application box in the heatsink, for fixing the components and application of a pulp grip and right palm grip for fittings and scans the label on the PCB, and finishing the visual and manual inspections with the application of the paste, removes the heatsink subset from the JIG.One of the points observed was the difficulty in reaching the lid, which is a little far from the worker, in the process under analysis, the left arm is used on the handle of the ivory cabinet on its right side, taking a label unit in a printer that it's far. Following the process, the worker removes the PCI main with all the parts from the assembly JIG, and proceeds with the arm abduction movements and the palm grip of the limbs on the part and positions it on the chassis in a thermal paste application JIG, pinching the fingers of the hands, in which the lid of the JIG is closed, performing rotation of the left shoulder and gripping the palm, as shown in Figure 10 C. The worker on the applicator handle, which has no sharp edges or protrusions and is dimensioned, as shown in Figure 10 D. To complete the process, a total of 6 applications are required, the worker returns the applicator to the support on her right side, performing arm flexion and palm grip, as shown in Figure 11 A.

Source: Authors, (2021).

Figure 11. JIG subset assembly activities and analysis

Then, the worker pushes the JIG, through a rail, to the box where the camera captures the image and analyzes the procedures, pressing the digital compression button of the left thumb while the right hand pushes the JIG to the box, performing the visualization, corrections and analysis for later results on a monitor in front of her, as shown in Figure 11B. With the approval of the scanning system, the worker pulls the JIG, placing it in its original position, opens cover and removes the assembled chassis, as shown in Figure 11C and performing the visual inspection and ends the work cycle by positioning the sub-assembly on the bench so that the worker at the next station has access, shown in Figure 11D.

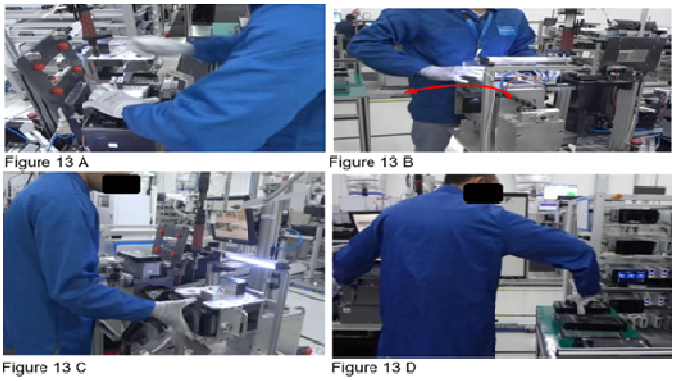
Evaluation of Station 4 - Mounting the Faceplate on the Chassis:



Source: Authors, (2021).

Figure 12. Activities and analysis of the Faceplate assembly on the Chassis.

The worker at this station is responsible for the final assembly of the device, receiving the chassis and the faceplate ready, adding the frontalplate and using JIGs for bolting, press and performing visual inspections, as shown in Figure 12A the workplace of the station. The worker's activities consist of picking up the frontalplate and assembling it on the chassis, picking up the faceplate and assembling it in a subassembly, screwing the subassembly, placing and removing the subassembly in a press, placing/removing the subassembly in a JIG, screwing the faceplate and making it available on a cart.In this cycle, the activities are carried out with the help of scanners and computers, the analyzes are performed standing and when the worker takes the chassis assembled with the PCI main on the bench at the previous station, performing flexion of the arms and palm grip, as shown in the Figure 12B then taking the scanner on its right side and reading the barcode on the chassis label assembled, as shown in Figure 12C.The process continues with the placement of the assembly JIG, performing pulp gripping and taking the ivory bottom case in front of it, performing pulp gripping and closing the JIG lid to start screwing, adopting pulp gripping and the sequence of 7 screws, holding the palm and flexing the right forearm to properly check the applied torque and pressure, as shown in Figure 12D. The worker opens the JIG cover and checks the product, making it necessary for the next step, as indicated in Figure 13A.



Source: Authors, (2021).

Figure 13. Faceplate mounting activities on the chassis

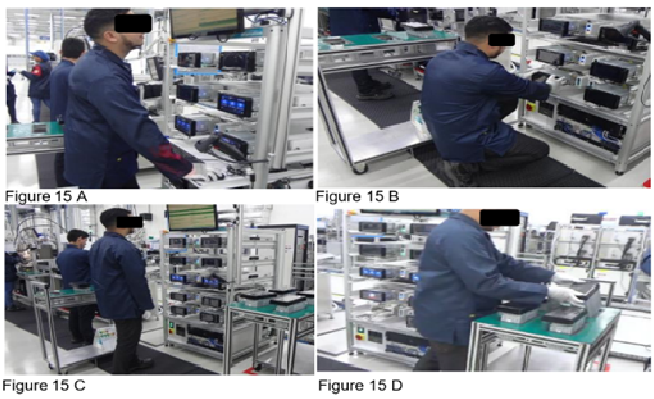
In this step, they are removed from the screwed chassis of the assembly JIG, performing pulp gripping, turning 45 degrees and inserting it into a thinking JIG, in which they require the movement of arms, forearms and require low effort and requiring the greatest expertise of the worker. Following the closing of the JIG cover of the press, the system then performs the fixing procedure (press fitting) of the faceplate to the chassis in a mechanized way, leaving the worker to observe for seconds the monitor in front of him the moment when the press releases the assembled radio. Then, the radio is positioned in the JIG, closing the cover in the sequence of screws, in which the worker performs the rotation of the JIG. This process is not so easy due to the need to hold the JIG handle and provide the gripping and rotation movements of the arms, being mandatory the 45 degree turns indicated in Figure 13 B.A sequence of 2 screws begins in top view, the worker rotates the JIG again in order to have access to the right side of the faceplate, performing palm grip and extension of the right arm, the process continues with sequences of 2 more screws for the appropriate fittings and tightening, performing another rotation of the JIG, leaving it in the original position, holding it through a side handle, which has space for placing your hands, for general analysis and verifying that there are no sharp edges or some changes, among others that may alter the quality of the product.At the end, digital compression of the thumbs and palm compression is necessary to hold and open the lid and after approval of the system, the worker removes the radius from the inside of the screwing JIG, performing palmar compression, as indicated in Figure 13C , ending the work cycle and positioning the radio on a cart so that the worker at the next station has easy access, as shown in Figure 13 D. It is important to note that after carrying out the bolting check process and analysis of the final product, the radio in this process is presented with a weight of 1.40 kg.

Rank 5 Assessment - AFT Functional Test: The worker at this post is responsible for carrying out the functional test on the devices that are tested in individual JIGs, in an automated way and without direct intervention by the worker, with the help of the monitor that is in front of him, as shown in Figure 14 A. Each device must be tested obligatorily coming from the previous post and remains from 9 to 12 min. in test. The activity consists of picking up the device on a cart, visually inspecting it, placing it in a test JIG, locking the JIG, scanning the device, monitoring the test, removing the device and placing it in the cart for the next post.The work cycle begins when the worker picks up the radio mounted on the workstation before his/her, performing palm grip and arm flexion, as indicated in Figure 14 B, performing a visual inspection on the radio and verifying that parts are well fitted, if screws are present, if there are any suspicious noises, etc. For this, he holds the radio in palmar grip and forearm flexion, in addition to neck flexion, bringing it closer to his field of vision, checking the cosmetic appearance of the radio, for scratches, discolorations and scratches, checking the LCD and buttons, according to Figure 14 C.

Source: Authors, (2021).

Figure 14. AFT functional test assembly activities

After visual visualizations, screws, fitted parts, among others, it is necessary to scan the radio in a scanner attached to the metallic structure of the test JIGs, as indicated in Figure 14 D.The entire action of the worker will depend on the release of the system, in which the position is verified, among the 10 available (5 on each side) and places the radius in one of the compartments, performing palm grip and close arm flexion. at 90 degrees for higher level placement. Regarding the placement of the radius in more intermediate positions, the worker performs flexion of the arms, as indicated in Figure 15 A. It was also verified that the worker adopts the posture of squatting or trunk flexion to place the radius in lower positions and higher or intermediate positions are also adopted depending on the situation to facilitate the activity to initiate the process of checking the operability of the product, as shown in Figure 15B.



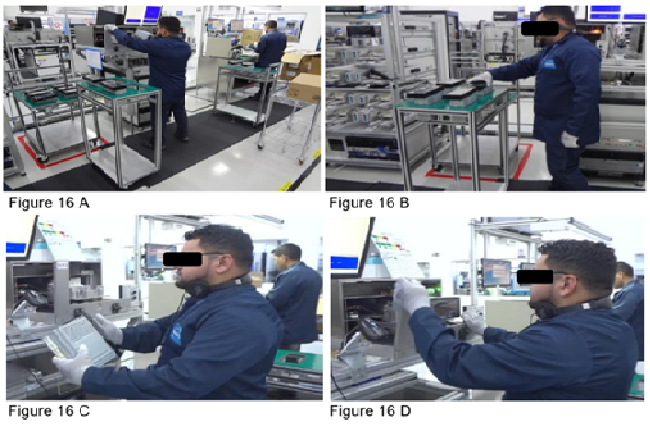
Source: Authors, (2021).

Figure 15. AFT functional test assembly activities

At this station, we have a greater analysis process with the aid of computers, scanners and visual control of the product and when

fitting the radio in the JIG, it is necessary to activate the front lever, sliding it from right to left in order to move the JIG backwards, connecting the various cables that will make the electrical connection, Wifi, radio, USB, among others, in order to start the test to verify the operability of the product and it becomes possible to lock of the JIG to start the radio check process and ending with the sliding of the left lever for later observations and analyzes carried out by the computer and the analyst.The test is done automatically by the software, the LCD needs to be turned on, to analyze if the functions are activated, the audio, image and camera tests that can last from 9 to 12 minutes, carried out without the intervention of the worker who only observes the monitor in front of him, in case of product defect, the worker needs to use the mouse and keyboard when used they serve for observations via the monitor in front of him I show the status of each JIG, presenting the tested, approved and failed items in different colors and easy to understand. After testing, the screen shows the word PASS on a green background, denoting approval or not, the worker removes the radio from the JIG, performing the same movements and ends the work cycle by placing the radio in a cart beside him so that the worker at the next station has easy access, performing hand grip and arm bending.

Assessment of rank 6 - MFT Functional Test: The worker is responsible for carrying out the functioning test of the finished devices, carried out in a JIG on a workstation, with two independent JIGs that perform the same test on two devices simultaneously. The worker follows the instructions on a monitor, performing the requested tasks, lasting about 3 minutes for each device. The tasks consist of picking up the device on a cart, visually inspecting it, scanning the device, placing it in a JIG, following the software guidelines, removing the device and placing it on a cart, as shown in Figure 16 A.At this station, it was observed that the worker takes the radio on the cart, performing palm grip and right arm flexion, as shown in Figure 16 B.



Source: Authors, (2021).

Figure 16. MFT functional test assembly activities

Following the scan attached to the test bench, as shown in Figure 16 C. After releasing the system, he performs the placement of the radio in a test JIG, fitting, the lever being operated to fix it and connect it to the power cables on the back of the device to evaluate the readings applicable to the software and the USB, Wifi, antenna and other devices necessary for performing the automatic test following the instructions on the monitor, as shown in Figure 16 D. The instructions and step-by-step instructions for the tests are presented in a split screen on the monitor, making the analyzes presented in a box, which is centralized, easier. the letters in readable color and size, with a clean layout and information that is easy to understand and in Portuguese, facilitating tasks such as pressing buttons to test audio, among others. Every task requested by the software, the pushbutton panel on its right side must be activated to confirm the execution so that the system defines the following coordinates in relation to the LCD colors using a plastic cone to darken the verification area, as shown in Figure 17 A.

Source: Authors, (2021).

Figure 17. MFT functional test assembly activities

Each radio remains in the test JIG for about 3 minutes, with the worker holding his hands close to the JIG to perform the requested tasks and confirm them in a buttonhole, requiring him to remain in the standing position and with his arms in flexion close to 90 degrees, having a height adjustment system, as indicated in Figure 17 B. Upon completion of the test, the software shows the approval of the radio unit, the worker makes the withdrawal by lowering the JIG lever, disconnecting, turning off and releasing the radio, shown in Figure 17 C. At the end of the work cycle, the radio is placed on a cart next to it so that the worker at the next station has access, as shown in Figure 17 D.

Assessment of Station 7 - Visual Inspection, packaging and Palletization: The worker at this station is responsible for packing the devices ready for packaging and delivery to the final customer. To complete the process, visual and manual inspections, cleaning and labeling will be carried out, ending the process with packaging and palletizing, as shown in Figure 18 A.

Source: Authors, (2021).

Figure 18. Activities carried out in visual inspections, packaging and palletizing

It is observed in this process the visual inspection of the radio indicated in Figure 18 B, with the affixing of labels and film for control in the system and placing the device in a collective box with 6 units and later the palletizing of the products that will be sent to the final customer. The workers consider the weight of the radio to be light due to its dimensions and fixed weight at 1.40 kg, due to the moderate effort due to the non-extended time in the activity, making it necessary to check the assembled items (screws, parts, etc.) and the appearance of the radio. (scratches, discoloration, dents, etc., lateral movements are necessary, reaching in order to check for loose parts inside, with palm grip and forearm flexion and hyperextension, lowering and raising the device, with light efforts, indicated in Figure 18 C. Sequencing the scan of the radius, with right palmar compression, as shown in Figure 18 D.After analysis, the gluing process begins with 3 labels on the back of the radio, as shown in Figure 19 A. The activities carried out at this station are considered by the operator as light pinching movements of the fingers that indicate that there was really an intention and the placement of labels that need to be evaluated in the next process will be inspected by the technical and operational team.

In the final phase of the process, the worker rotates the radio in a JIG, applying a film and labels on the LCD on a support on the bench, using the gluing orientation frame, including cleaning, making scanning necessary of the parts, with the help of a scanner that is easy to locate and use the equipment to complete a work cycle, placing theradio in a collective box next to it, as shown in Figure 19 B.In this step, the flaps of the box are closed, which is placed on a pallet on a pantograph cart, shown in Figure 19 C, weighing 9.44 kg in a full box. To speed up the packaging process, empty boxes are placed close to the worker, placed in support of the rails next to the bench and are used for the storage and stacking of finished products and placed on a pallet, in a position closer to the bench, since the areas are far from you, as shown in Figure 19 D. The radio production cycle tends to complete its validation with the arrangement on the pallet with boxes containing 15 units, with 5 layers with 5 boxes each, so the pallet is inspected, approved and released for storage, transport and distribution to stores and customers.

Source: Authors, (2021).

Figure 19. Activities performed in visual inspections, packaging and palletizing

Table 2. Mouting of faceplate

		LEVEL OF EFFORT		TIME OF EFFORT		EFFORT PER MINUTE		Classification	
		1 - Low **2** - Moderate **3** - Heavy		**1** - 0 a 6 sec **2** - 6 a 20 sec **3** - 20 a 30 sec **4** - > 30 sec		**1** - 0 a 1 effort **2** - 1 a 5 effort **3** - 5 a 15 effort **4** - > 15 effort			
		E	D	E	D	E	D	E	D
NECK	A/D	1		2		3			
SHOULDERS	A	1	1	1	1	3	3		
	B		2		1		2		
	C	2	2	1	1	2	2		
	D	2	2	1	1	2	2		
BODY	A/D	1		2		2			
ARMS FOREARMS	A	1	1	1	1	3	3		
	B		2		1		2		
	C	2	2	1	1	2	2		
	D	2	2	1	1	2	2		
HANDS FINGERS FIST	A	2	2	1	1	3	3		
	B		2		1		2		
	C	2	2	1	1	2	2		
	D	2	2	1	1	2	2		

RESULT

GREEN	Others Combinations
YELLOW	1 2 3 1 3 2 2 1 3 2 2 2 2 3 1 2 3 2 3 1 2
RED	2 2 3 3 1 3 3 2 1 3 2 2
VIOLET	3 2 3 3 3 1 3 3 2 X 4 X X X 4

FINAL RESULT: MODERATE RISK

Source: Authors, (2021).

Table 3: Respective system numbers with fuzzy logic

Level of Effort	Time of Effort	Effort per Minute
1 = 15 2 = 55 3 = 90	1 = 4 2 = 15 3 = 28 4 = 45	1 = 0,5 2 = 3 3 = 10 4 = 23

Source: Authors, (2021).

Application of fuzzy logic in AET: After analyzing the movements of the upper limbs (neck, shoulder, trunk, arms, hands, fingers and wrists) of the industrial process of manufacturing car radios carried out with the knowledge of the ergonomics specialist, based on the Suzanne Rodgers methodology in the seven stations studied, it becomes necessary to include fuzzy logic to obtain the results that will be presented at the end of this study.

Expert view with the inclusion of fuzzy logic: As previously discussed, the specialist tends to choose the best tool to be applied after his field analysis and in this article the tool chosen and appropriate by the specialist was the Suzanne Rodgers methodology, in which we will describe the sequence of understanding that was used combined with the logic fuzzy.In the seven workstations, AET was observed in the movement of the upper limbs, in the main tasks evaluated, which involved: pinching, cable connections, film placement, labeling, hand grips, screws, scanners, arm flexion and rotation. of the body starting at post 1 to post 7.In the Suzanne Rodgers methodology, movements of the neck, shoulders, trunk, arms and forearms, hands, fingers and wrists with the respective ones (assessments of the levels of effort that vary from low, moderate and heavy), (time of effort that vary from zero seconds until greater than 30 seconds) and ending (effort per minute that starts at 0 efforts until greater than 15 efforts) that follow in the tables that are well explained with the use of numbers that were applied according to the observations and descriptions discussed above in the text.The evaluations start at post 1 with the results of table 2, in which the neck

Table 4. Respective number models of the system with fuzzy logic

Tasks	Members	Level of Effort	Time of Effort	Effort per Minute	Variables	Linguistic Variable
A	A	15	4	0,5	0,555	
B	B	55	15	3	1,92	
C	C	90	28	10	0,0	
D	D	0,0	45	23	0,0	

Source: Authors, (2021).

Table 5. Simulation done with fuzzy logic

Members	Evaluated Talks	Level of Effort		Time of Effort		Effort per Minute		Result	
		Left	Right	Left	Right	Left	Right	Left	Right
Neck	A/D	15		15		10		1,92	
Shoulders	A	15	15	4	4	10	10	0,555	0,555
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	55	55	4	4	3	3	0,555	0,555
Body	A/D	15		15		3		0,555	
Arm Forearms	A	15	15	4	4	10	10	0,555	0,555
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	55	55	4	4	3	3	0,555	0,555
Hands Fist Fingers	A	55	55	4	4	10	10	1,92	1,92
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	55	55	4	4	3	3	0,555	0,555

Source: Authors, (2021).

Table 6. Test display and frontalplate mounting

EVALUATED TASKS

A	Clamping remove the filme from the faceplate scan, place and remove the faceplate from the test JIG activate the push button position the frontalplate on the JIG pick up and paste the label arrange on the table

EVALUATED TASKS

B	Grip: screw 4x with equipament electronic and scan
C	Arm bending: removing materials in the containers
D	Arm rotation move the JIG cover and JIG cradle

LEVEL OF EFFORT	TIME OF EFFORT	EFFORT PER MINUTE
1 - Low	1 - 0 a 6 sec	1 - 0 a 1 effort
2 - Moderate	2 - 6 a 20 sec	2 - 1 a 5 effort
3 - Heavy	3 - 20 a 30 sec	3 - 5 a 15 effort
	4 - > 30 sec	4 - > 15 effort

		E	D	E	D	E	D	Classification E	Classification D
NECK	A/D	1		2		3			
SHOULDERS	A	1	1	1	1	3	3		
	B		2		1		2		
	C	2	2	1	1	2	2		
	D	3	3	1	1	1	1		
BODY	A/D	1		2		2			
ARMS FOREARMS	A	1	1	1	1	3	3		
	B		2		1		2		
	C	2	2	1	1	2	2		
	D	3	3	1	1	1	1		
HANDS FINGERS FIST	A	2	2	1	1	3	3		
	B		2		1		2		
	C	2	2	1	1	2	2		
	D	3	3	1	1	1	1		

RESULT

GREEN	Other Combinations
YELLOW	1 2 3 1 3 2 2 1 3 2 2 2 2 3 1 2 3 2 3 1 2
RED	2 2 3 3 1 3 3 2 1 3 2 2
VIOLET	3 2 3 3 3 1 3 3 2 X 4 X X X 4

FINAL RESULT: MODERATE RISK

Source: Authors, (2021).

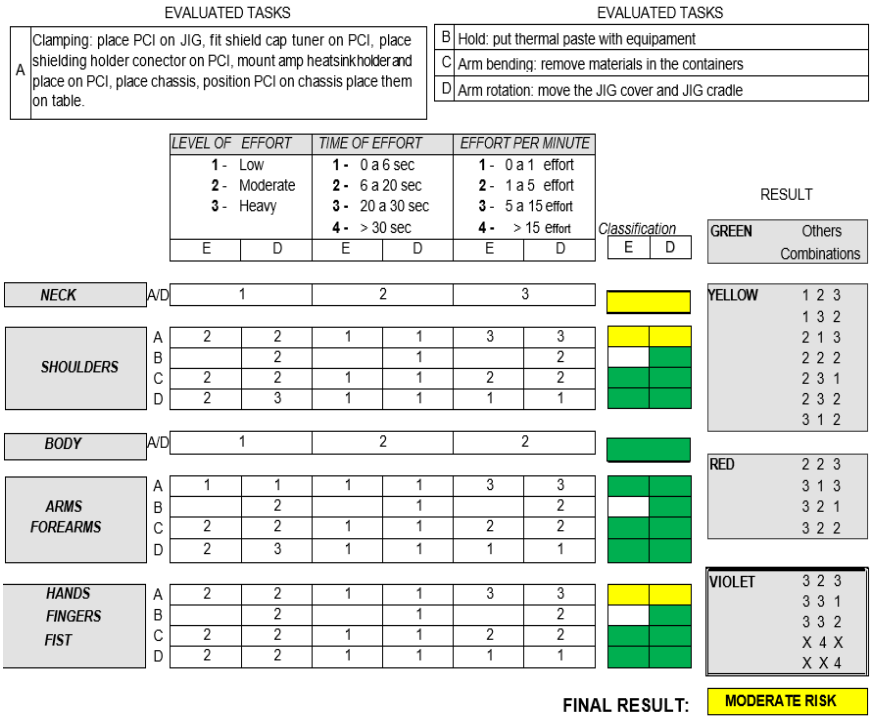
was identified with a low level of effort, low effort time and moderateeffort per minute with the following combinations (1,2,3) and hands, wrists and fingers by low effort level, low effort time and moderate effort per minute with the combinations (2,1,3) defined in the Suzanne Rodgers methodology by the yellow color for the combinations considered moderate risk.The data in Table 2 must be correct and adequate to the reality of the worker, these data show the movements carried out in the upper and lower limbs of the workers, also including the observations that are made in relation to the use of work tools, layout, air conditioning, lighting, etc. In the application of fuzzy logic, it was observed that in the movements of the neck, shoulders, trunk, arms and forearms, hands, fingers and wrists with the respective evaluations: Levels of effort that vary from low, moderate and heavy, Time of effort that vary from zero seconds to greater than 30 seconds and ending the Effort for minutes that starts at 0 efforts until greater than 15 efforts are replaced by numerical variables below with the following values. In matlab, you must replace all the values that were described by the ergonomics professional presented and filled in Table 2 and with the data from table 3 that must help and replace with the same equivalence for the creation of Table 4, resulting in the simulation of fuzzy logic . The output variables were 0.555 for the green color considered (low risk) and 1.92 for the yellow color (moderate risk), as shown in Table 4, the activity risk is considered moderate. In the case of the linguistic variables of red and violet, they were not considered in this article due to the non-framing of heavy risk for red or levels above the allowed in the case of the color violet.From now on, the numerical values described in Table 4 will be applied in the tables and applied in Table 5, according to the model including fuzzy logic for later comparison with the expert's data and the Matlab data. In which, it was observed that in Table 5, there was no change of what has already been addressed and the results are equivalent and making it clear to lay or professional evaluators that the results are practically the same.At station 2, display test and faceplate assembly with the following results presented in Table 6, in which the neck was identified with low effort level, low effort time and moderate effort per minute with the following combinations (1,2,3) and hands, wrists and fingers by low effort level, low effort time and moderate effort per minute with the combinations (2,1,3) the results found in the methodology of Suzanne Rodgers were evaluated, classified by the color yellow by the combinations of activity at moderate risk.

Table 7. Simulation made with fuzzy logic

Members	Evaluated Talks	Level of Effort		Time of Effort		Effort per Minute		Result	
		Left	Right	Left	Right	Left	Right	Left	Right
Neck	**A/D**	15		15		10		1,92	
Shoulders	**A**	15	15	4	4	10	10	0,555	0,555
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	90	90	4	4	0,5	0,5	0,555	0,555
Body	**A/D**	15		15		3		0,555	
Arm Forearms	**A**	15	15	4	4	10	10	0,555	0,555
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	90	90	4	4	0,5	0,5	0,555	0,555
Hands Fist Fingers	**A**	55	55	4	4	10	10	1,92	1,92
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	90	90	4	4	0,5	0,5	0,555	0,555

Source: Authors, (2021).

Table 8. Mounting the PCI main in the chassis



Source: Authors, (2021).

It was observed that in Table 7, there was no significant change from what has already been discussed and the results are equivalent and making it clear to lay or professional evaluators that the results are practically the same. If there are no substantial changes, it is understood that the application of fuzzy logic can be clearly understood by observing the colors and numbers of the linguistic variables and output variables, proposed in the tables in sequence. At station 3 Assembly of the PCI main in chassis with the following results presented in Table 8, in which the neck with low effort level, low effort time and moderate effort per minute with the following combinations (1,2,3). Shoulders (2,1,3) moderate, and hands, wrists and fingers by low effort level, low effort time and moderate effort per minute with the combinations (2,1,3) the results found in Suzanne's methodology were evaluated Rodgers ranked yellow by moderate risk activity combinations.It is observed that in Table 9, there was no significant change of what has already been discussed and the results are equivalent and making it clear to lay or professional evaluators that the results are practically the same. If there are no substantial changes, it is understood that the application of fuzzy logic can be clearly understood by observing the colors and numbers of the linguistic variables and output variables.At station 4, assembly of the faceplate on the chassis with the results presented in Table 10, in which the neck was identified with a low level of effort, low effort time and effort per minute, with the following combinations (1,2,3), shoulders (2,1,3) moderate, arms and forearms (2,1,2) and (2,1,3) and hands wrists and fingers for low effort level, low effort time and moderate effort per minute with the combinations (2,1,3) and (2,1,2) when evaluating the results found in the methodology of Suzanne Rodgers is classified by the colors green and yellow by the combinations of activity and the risks involved and by the analysis of the applied study, the post is concluded by the moderate risk.It was observed that in Table 11, there was no significant change from what has already been discussed and the results are equivalent and making it clear to lay or professional evaluators that the results are practically the same. If there are no substantial changes, it is understood that the application of fuzzy logic can be clearly understood by observing the colors and numbers of the linguistic variables and output variables.In post 5 AFT functional test with the following results presented in Table 12, in which the neck with low effort level, low effort time and moderate effort per minute was identified with the following combinations (1,2,3) and hands wrists and fingers by low effort level, low effort time and moderate effort per minute with the combinations (2,1,3) the results found in the methodology of Suzanne Rodgers were evaluated, classified by the yellow color by the combinations of activity with moderate risk.It was observed that in Table 13, there was no significant change from what has already been discussed and the results are equivalent and making it clear to lay or professional evaluators that the results are

Table 9. Simulation with fuzzy logic

Members	Evaluated Talks	Level of Effort		Time of Effort		Effort per Minute		Result	
		Left	Right	Left	Right	Left	Right	Left	Right
Neck	A/D	15		15		10		1,92	
Shoulders	A	55	55	4	4	10	10	1,92	1,92
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	55	90	4	4	0,5	0,5	0,555	0,555
Body	A/D	15		15		3		0,555	
Arm Forearms	A	15	15	4	4	10	10	0,555	0,555
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	55	90	4	4	0,5	0,5	0,555	0,555
Hands Fist Fingers	A	55	55	4	4	10	10	1,92	1,92
	B		55		4		3		0,555
	C	55	55	4	4	3	3	0,555	0,555
	D	55	55	4	4	0,5	0,5	0,555	0,555

Fonte: Autores, (2021).

Table 10. Mounting the faceplate to the chassis

A	Pinching and palm grip. position chassis on JIG mount bottom case on chassis, position chassis on press, mount faceplate on chassis, position chassis on bolting JIG.
B	Grip: screw 11x with electronic equipament and scan
C	Arm bending: Removing materials in the containers
D	Arm rotation: Move JIG cover, rotate screw JIG

LEVEL OF EFFORT	*TIME OF ESFORÇO*	*EFFORT PER MINUTE*
1 - Low	**1 -** 0 a 6 sec	**1 -** 0 a 1 effort
2 - Moderate	**2 -** 6 a 20 sec	**2 -** 1 a 5 effort
3 - Heavy	**3 -** 20 a 30 sec	**3 -** 5 a 15 effort
	4 - > 30 sec	**4 -** > 15 effort

		E	D	E	D	E	D	*Classification* E	D
NECK	A/D	1		2		3			
SHOULDERS	A	2	2	1	1	3	3		
	B		2		1		3		
	C	2	2	1	1	2	2		
	D	2	2	1	1	3	3		
BODY	A/D	1		2		2			
ARMS FOREARMS	A	2	2	1	1	3	3		
	B		2		1		3		
	C	2	2	1	1	2	2		
	D	2	2	1	1	3	3		
HANDS FINGERS FIST	A	2	2	1	1	3	3		
	B		2		1		3		
	C	2	2	1	1	2	2		
	D	2	2	1	1	3	3		

RESULT

GREEN	Other Combinations
YELLOW	1 2 3
	1 3 2
	2 1 3
	2 2 2
	2 3 1
	2 3 2
	3 1 2
RED	2 2 3
	3 1 3
	3 2 1
	3 2 2
VIOLET	3 2 3
	3 3 1
	3 3 2
	X 4 X
	X X 4

FINAL RESULT: **MODERATE RISK**

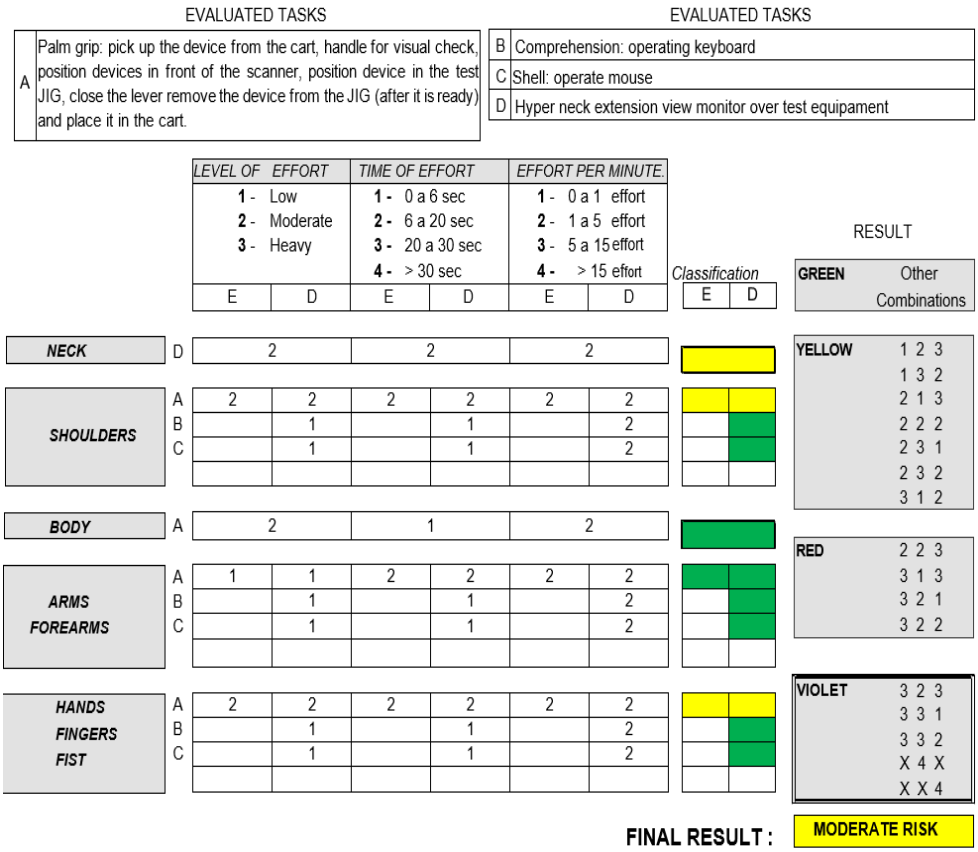
Source: Authors, (2021).

Table 11. Simulation done with fuzzy logic

Members	**Evaluated Talks**	**Level of Effort**		**Time of Effort**		**Effort per Minute**		**Result**	
		Left	Right	Left	Right	Left	Right	Left	Right
Neck	**A/D**	15		15		10		1,92	
Shoulders	**A**	55	55	4	4	10	10	1,92	1,92
	B		55		4		10		1,92
	C	55	55	4	4	3	3	0,555	0,555
	D	55	55	4	4	10	10	1,92	1,92
Body	**A/D**	15		15		3		0,555	
Arm Forearms	**A**	55	55	4	4	10	10	1,92	1,92
	B		55		4		10		1,92
	C	55	55	4	4	3	3	0,555	0,555
	D	55	55	4	4	10	10	1,92	1,92
Hands Fist Fingers	**A**	55	55	4	4	10	10	1,92	1,92
	B		55		4		10		1,92
	C	55	55	4	4	3	3	0,555	0,555
	D	55	55	4	4	10	10	1,92	1,92

Source: Authors, (2021).

Table 12. AFT Functional Test



Source: Authors, (2021).

Table 13. Simulation made with fuzzy logic

Members	Evaluated Talks	Level of Effort		Time of Effort		Effort per Minute		Result	
		Left	Right	Left	Right	Left	Right	Left	Right
Neck	D	55		15		3		1,92	
Shoulders	A	55	55	15	15	3	3	1,92	1,92
	B		15		4		3		0,555
	C		15		4		3		0,555
Body	A	55		4		3		0,555	
Arm Forearms	A	15	15	15	15	3	3	0,555	0,555
	B		15		4		3		0,555
	C		15		4		3		0,555
Hands Fist Fingers	A	55	55	15	15	3	3	1,92	1,92
	B		15		4		3		0,555
	C		15		4		3		0,555

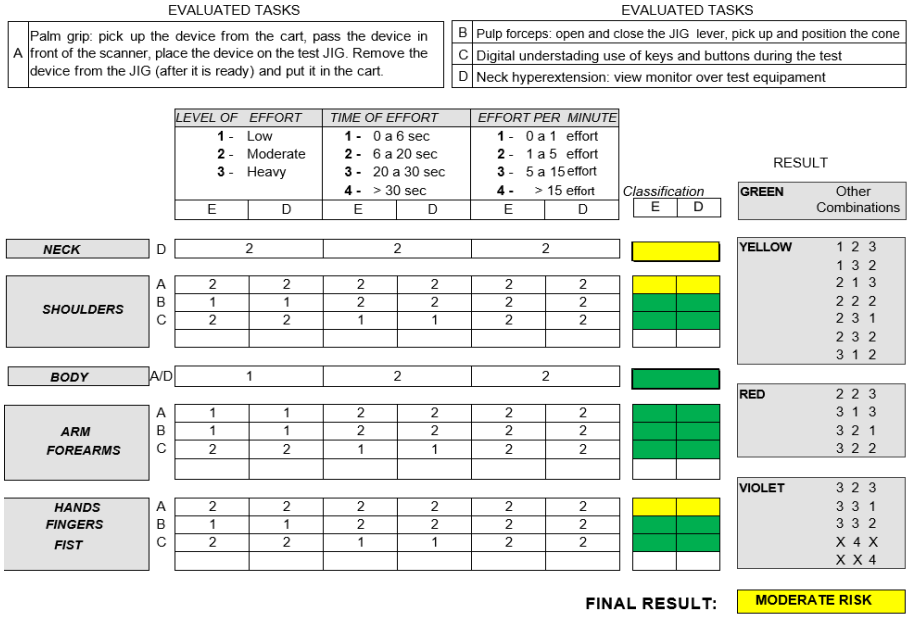
Source: Authors, (2021).

practically the same. If there are no substantial changes, it is understood that the application of fuzzy logic can be clearly understood by observing the colors and numbers of the linguistic variables and output variables.In post 6 MFT functional test with the following results presented in Table 14, in which the neck with low effort level, low effort time and moderate effort per minute with the following combinations (1,2,3) and hands were identified wrists and fingers by low effort level, low effort time and moderate effort per minute with the combinations (2,1,3) the results found in the methodology of Suzanne Rodgers were evaluated, classified by the yellow color by the combinations of activity with moderate risk.At station 7 Packing and palletizing with the following results shown in Table 16, in which the neck was identified with low effort level, low effort time and moderate effort per minute with the following combinations (1,2,3) and hands wrists and fingers by low effort level, low effort time and moderate effort per minute with the combinations (2,1,3) the results found in the methodology of Suzanne Rodgers were evaluated, classified by the color yellow by the combinations of activity with moderate risk. It was observed that in Table 17, there was no significant change of what has already been discussed and the results are equivalent and making it clear to lay or professional evaluators that the results are practically the same. If there are no substantial changes, it is understood that the application of fuzzy logic can be clearly understood by observing the colors and numbers of the linguistic variables and output variables.

Fuzzy results for decision making

The modeling of fuzzy logic based on the Suzanne Rodgers methodology in Figure 21, presents trapezoidal functions and pertinence that are analyzed the variables under analysis has four levels of inference, namely: "Null", "Low", "Moderate" and " Heavy" that are clearly identified after inputting data to the system.

Table 14 - MFT functional test



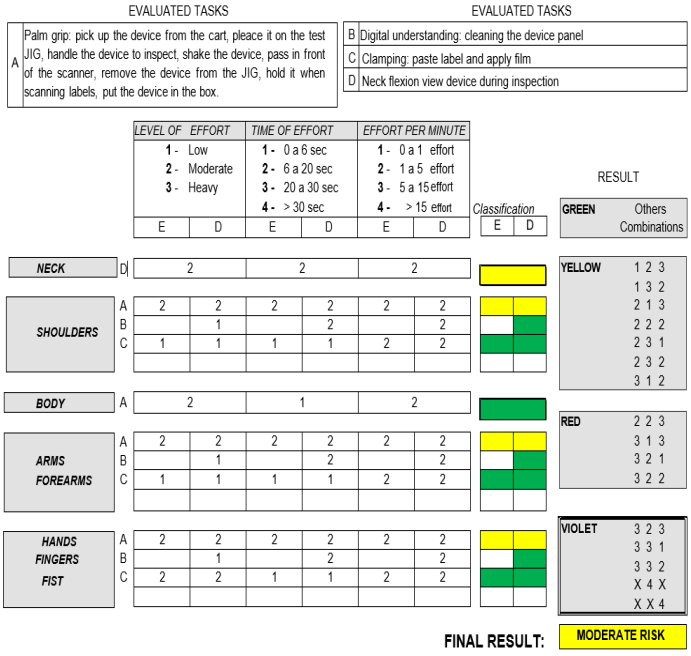
Source: Authors, (2021).

Table 15. Simulation done with fuzzy logic

Members	Evaluated Talks	Level of Effort		Time of Effort		Effort per Minute		Result	
		Left	Right	Left	Right	Left	Right	Left	Right
Neck	D	55		15		3		1,92	
Shoulders	A	55	55	15	15	3	3	1,92	1,92
	B	15	15	15	15	3	3	0,555	0,555
	C	55	55	4	4	3	3	0,555	0,555
Body	A/D	15		15		3		0,555	
Arm Forearms	A	15	15	15	15	3	3	0,555	0,555
	B	15	15	15	15	3	3	0,555	0,555
	C	55	55	4	4	3	3	0,555	0,555
Hands Fist Fingers	A	55	55	15	15	3	3	1,92	1,92
	B	15	15	15	15	3	3	0,555	0,555
	C	55	55	4	4	3	3	0,555	0,555

Source: Authors, (2021).

Table 16. Packing and palletizing

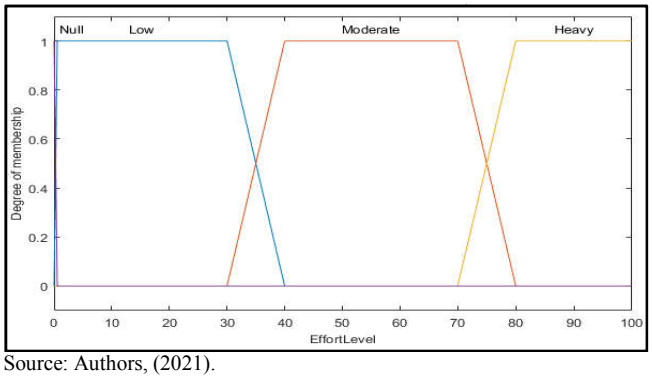


Source: Authors, (2021).

Table 17. Simulation done with fuzzy logic

Members	Evaluated Talks	Level of Effort		Time of Effort		Effort per Minute		Result	
		Left	Right	Left	Right	Left	Right	Left	Right
Neck	D	55		15		3		1,92	
Shoulders	A	55	55	15	15	3	3	1,92	1,92
	B		15		15		3		0,555
	C	15	15	4	4	3	3	0,555	0,555
Body	A	55		4		3		0,555	
Arm Forearms	A	55	55	15	15	3	3	1,92	1,92
	B		15		15		3		0,555
	C	15	15	4	4	3	3	0,555	0,555
Hands Fist Fingers	A	55	55	15	15	3	3	1,92	1,92
	B		15		15		3		0,555
	C	55	55	4	4	3	3	0,555	0,555

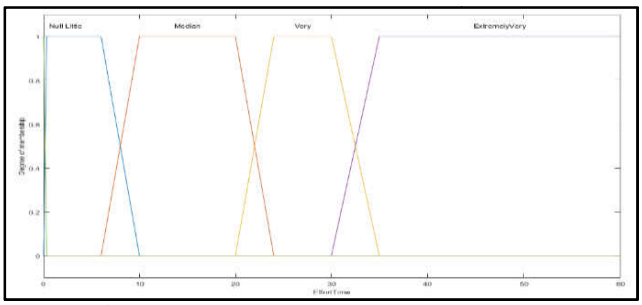
Source: Authors, (2021).



Source: Authors, (2021).

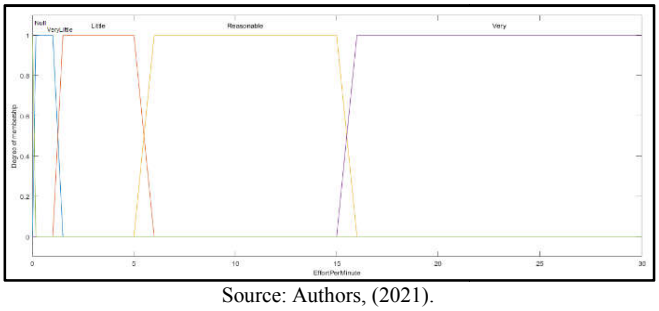
Figure 21. Simulation done with fuzzy logic at the level of effort applied to the activities

Figure 22 shows the modeling of the effort time applied by the worker in the seven workstations and its importance for a visual analysis of the behavior of the degree of relevance of this function is shown below. In which it has five levels of inference, being null, little, medium, a lot, too much demonstrated in the modeling.



Source: Authors, (2021).

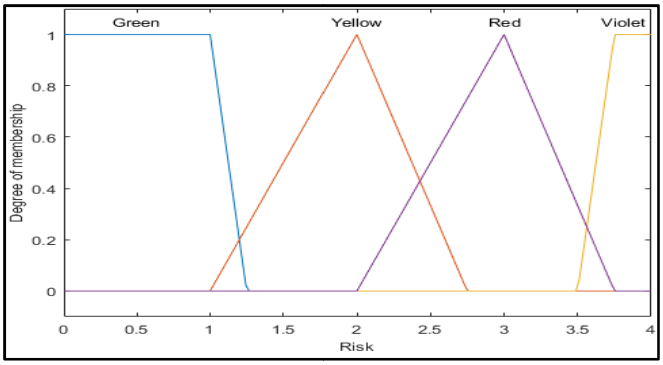
Figure 22. Simulation made with fuzzy logic time of effort applied in activities



Source: Authors, (2021).

Figure 23. Simulation made with fuzzy logic at effort per minute applied to activities

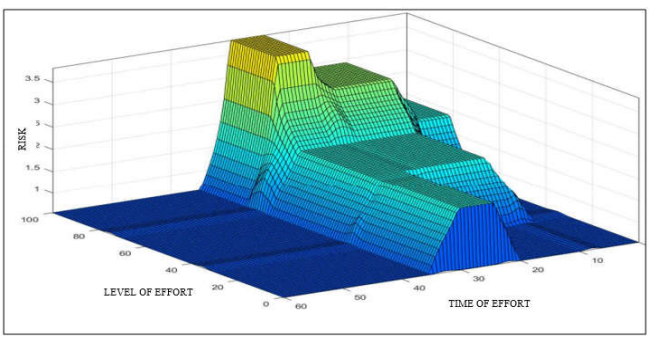
Figure 23 shows the modeling of the effort per minute applied by the worker in the seven workstations and its importance for a visual analysis of the behavior of the degree of relevance of this function is shown below. In which it has five levels of inference, being them null, very little, reasonable. Figure 24 presents the output variables with the final result in which it is desired to achieve the results in thedenominations of "risks and combinations" called "Green", "Yellow", "Red" and "Violet.Figure 24: Simulation made with fuzzy logic to the risk applied in the activities.



Source: Authors, (2021).

Figure 24. Simulation made with fuzzy logic to the risk applied in the activities

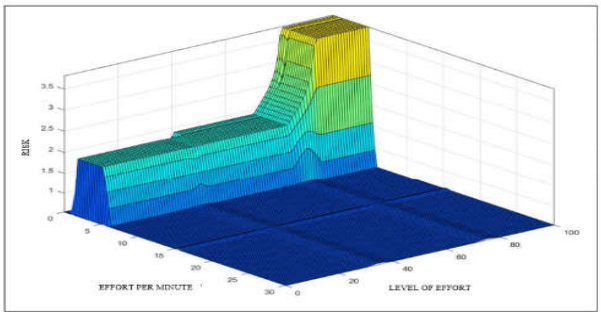
Surface graphics: A surface graph is a graph that determines the desired response values and operating conditions, containing the following elements in its three-dimensional structure to obtain responses or predictions presented on the x and y axes when we place the numerical values of the logic rule bases fuzzy. Figure 25 presents a view of a work station with the insertion of input and output variables and the degree of relevance shown in the images after the insertion of numerical values of effort level on the X axis and effort time on the Y axis and observed A change in the behavior of the graph and the pertinence to risk on the Z axis in the modeling was observed.



Source: Authors, (2021).

Figure 25. Effort level surface graph with effort time

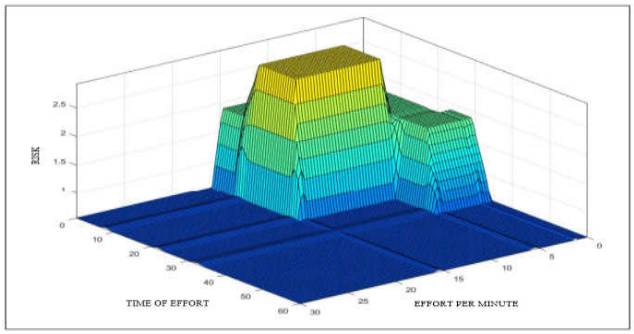
Figure 26 presents the result of the graphical view of the workstation with the insertion of input and output variables and the degree of relevance presented, after the insertion of numerical values of effort level on the X axis and effort per minute on the Y axis and there was a change in the behavior of the graph and the risk pertinence on the Z axis.



Source: Authors, (2021).

Figure 26. Graph of surface effort per minute with level of effort

Figure 27 presents a view of the workstation with the insertion of input and output variables and the degree of relevance presented in the images after the insertion of numerical values of effort per minute on the X axis and effort time on the Y axis and observed- if a change in graph behavior and risk relevance on the Z axis.



Source: Authors, (2021).

Figure 27. Effort time surface graph with effort per minute.

Figure 28. Legend of risk classification in activities

Risk	Combinations		
Green	Other Combinations		
Yellow	1	2	3
	1	3	2
	2	1	3
	2	2	2
	2	3	1
	2	3	2
	3	1	2
Red	2	2	3
	3	1	3
	3	2	1
	3	2	2
Violet	3	2	3
	3	3	1
	3	3	2
	X	4	X
	X	X	4

Source: Authors, (2021).

Simulation Result: The results were grouped in Figure 28. In which it was verified that the output variables are identified by the risks and color combinations, in which it is possible to see in the legend the indications of possible ergonomic risks:

- **Green:** It is an indication that the risk of injury is very low (acceptable value)
- **Yellow:** It is an indication that a certain risk is moderate, and that it must be treated so that the risk decreases;
- **Red:** It is an indication of high risk that actions should be taken immediately
- **Violet:** It is indicative of high risk and musculoskeletal problems can arise immediately

CONCLUSION

In the course of this study, the identification of ergonomic risk factors that interfere in activities and jobs was observed, as well as the possibility of Repetitive Strain Injury / Work Related Steeomuscular Disease (RSI/WRSD) through AET. The study confirmed the importance of ergonomics in the investigation of aspects related to occupational diseases, and for the real prevention of occupational diseases to exist, the participation of companies and employees identified by the average ergonomic risk characterized by the Suzanne Rodgers method and some adjustments in the movements lower and upper limbs of employees and machinery in relation to distances.Regarding the application of fuzzy logic applied to the ergonomic tool through the Suzanne Rodgers method presented in table 2, with the use of numerical criteria and observations of movements of the lower and upper limbs. The values found in the AET during the observation and annotation stages were applied in the fuzzy modeling and the results presented favor similar observations in the language of the ergonomics professional, the same language of the worker described in tables 5 to table 14 and subsequent emergence of linguistic variables chosen at analyst's discretion. In the present study, the color option described in item 4.2.12 was chosen.Acho melhor refazer ou excluir conforme solicitação da banca de disssertação ou deixar assim Figure 28 shows the caption for the classification of ergonomic risks of the activity analyzed in this article and the evaluation in the linguistic variable of yellow color (moderate risk) is highlighted, according to the lack of company shares, the rich tend to increase through combinations in the post 1 of table 5 to the other posts, resulting in a combination after reassessment that can benefit the post, impact or cause musculoskeletal disorders to workers.In a simple view, the worker, when observing that through the colors, it becomes necessary his effective participation in relation to his postures, observations and participation in the improvement of the processes applied to the work place according to the result of the defuzzification described in table 28. company to adopt corrective actions in organizations to minimize or reduce possible musculoskeletal diseases applied to workers. The research would need more data such as (noise, heat) and other observations that could be added to the AET, making it more complete. In this study, the methodology met expectations and can be expanded for further research and studies in other productive activities such as: civil construction, hotels, supermarkets, etc.

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