Application of the Lean Manufacturing Process in the Practical Lessons of the Course Learning in Industrial Mechanical Maintenance in Senai José Ignácio Peixoto Vocational Training Center

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Abstract

The present work was developed with the purpose of conducting a case study and applying Lean Manufacturing in the practical classes of a technical school of a technical school in the Zona da Mata Mineira, identifying, quantifying and reducing the wasted time and quantity of actions performed by the students during class. For the development of the research, data were collected performing on-site monitoring. The Kaizen, A3 Report, Chronoanalysis and Spaghetti Diagram tools were applied. Data were then collected again, which were processed through statistical software Minitab 17, performing a significance analysis, correlating the data collected before and after the application of the methodology. It was concluded that the changes were enough to reduce the movement, the time of actions that do not add value to the student and increase the numbers of actions that add value to the student.

Keywords - *Lean manufacturing, waste, chronoanalysis*

I. INTRODUCTION

With the development of globalization, the competitiveness of the world market becomes even more intense, which demands lower costs and improved quality and productivity indices. The struggle for survival of companies, together with the efficiency of technology, has given rise to new management techniques, which put organizations in constant change creating efficient management techniques to reach the parameters stipulated by society. Companies increasingly focus on their area of expertise, for which it is essential to optimize the resources used. Due to the importance of the optimization of resources and processes, Lean Manufacturing was used to reduce existing waste in the production system.

The general objective of the work is the implementation of lean manufacturing in the practical lessons of the Industrial Maintenance Mechanic course offered by the Senai José Ignácio Peixoto Professional Training Center in the city of Cataguases, Minas Gerais. The specific objectives are: to identify, quantify and reduce the wastes related to the numbers of actions taken by the students and their time during the practical classes.

II. REVIEW OF LITERATURE

A. Lean manufacturing concept

Production System is defined by [1] as a set of elements that work together to achieve a common goal, receiving inputs and producing results in a systematic method of transformation.

Originated from English, lean, lean production is also known as Toyota Production System (STP). Indicated by [2] as an efficient, agile, flexible, innovative production system that surpasses the mass production that adapts more easily to the market and its constant changes.

B. Search method

According to [3] the questionnaire is a research method that aims to gather information based on the inquisition of a representative group of the study population.

According to [4], in any scientific estimation, there may be a random error, causing a reduction in accuracy. In this way, reliability is referred to the accuracy of the estimation of what is measured. The measure of confidence of a questionnaire, points out how unequal the items measure the same concept. Cronbach's Alpha is the most widely used.

C. Statistical Methods

According to [5], the technique of collecting or selecting elements of a study, is determined by a sampling design of the research. When samples are collected for convenience, there is a risk of not being faithfully represented in the study population. According to [6], to measure the time spent by an operator in the execution of a given task, a method called chronoanalysis is used. [7] reports that a very

effective chrono-analysis tool is timing, since it points out significant points for a time sampling.

D. Lean Tools

According to [8], several programs and tools are used by the industry to improve productivity through the reduction of waste, some of these programs and tools addressed in the literature and widely used by industries are mentioned below.

E. Spaghetti Diagram

According to [9], the spaghetti diagram is named because of its resemblance to a spaghetti-type pasta dish.

F. Kaizen

According to [10], the word Kaizen has a Japanese origin that means change for the better, is known in companies as continuous improvement.

G. Report A3

According to [1], the A3 report is a method that is based on the detection and resolution of problems in which they are mounted on A3 paper, so it receives this denomination. Already [11], reports that some steps must be taken to determine the work context and relevance of a problem to describe problems, establish goals, verify causes, propose solutions and plan of action.

H. Statistical software

[12], explains that Minitab is software aimed at statistical purposes, referenced in several literatures and widely used in engineering courses.

I. Hypothesis Test and Significance

According to [13], the fundamental function of the statistical analysis is to determine if there is statistical significance in the results according to predetermined limits. [14] reports that the level of significance is a limit adopted to declare if a deviation comes from coincidence or not, accepting values with $P = 0.05$ and $P = 0.01$. Still according to [14], it is necessary to determine hypotheses so that something can be tested. The null hypothesis H0 is considered true if tests do not indicate otherwise and H1 is the alternative hypothesis, opposite H0.

III. METHODOLOGY

For the development of the present work, a review of the literature was carried out using scientific articles researched in Google Academic, Scielo and Capes. A case study was carried out with the purpose of identifying and quantifying the wasted time and quantity of students' actions in the practical classes of the Maintenance Mechanic course, with 660 hours of practical classes and 440 hours of theoretical classes. Senai, José Ignácio Peixoto Professional Training Center, located.

A. Preliminary Diagnosis

Initially, a structured questionnaire was developed with 12 questions to be applied to course instructor:

1-Is there constant movement of the students during the execution of their practices?

2 - Based on your knowledge is it possible to reduce student movement?

3 - Is there constant waiting for the students to use the machines and / or tooling?

4 - Based on your knowledge is it possible to reduce student waiting?

5 - Is there constant transport of parts between benches and / or machines?

6 - Based on your knowledge is it possible to reduce this piece transport?

7 - Are there too much processing by students in practical activities?

8 - In your opinion, is the student learning by doing more processes than necessary?

9 - Based on your knowledge is it possible to reduce this over-processing?

10 - Do the students perform rework constantly during the execution of their practices?

11 - In your opinion, is the student learning by doing the wrong task?

12 - Based on your knowledge is it possible to reduce this amount of rework?

The questionnaire has a quantitative character and includes questions aiming to collect data regarding movement, waiting, transportation of parts, rework and reprocessing of students.

B. Validation of the questionnaire

After the questionnaire was constructed, it was applied as a pre-test in 9 units of Senai in the state of Minas Gerais, obtaining 61 answers. The validation of the questionnaire was done in principle by the use of the binary tree, in which the answers were converted to 0 for non-occurrence and 1 for the occurrence. In order to perform the calculations, questions 2, 3, 4, 5, 7, 8, 9, 10 and 12 were used. The Cronbach's alpha coefficient was then obtained through the statistical software Minitab 17.
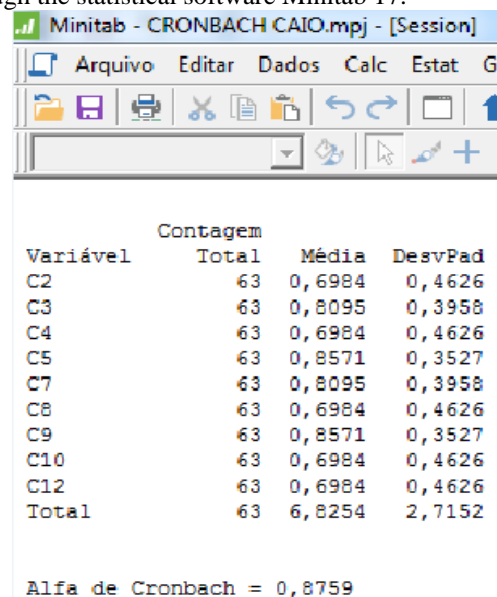

Fig. 1 – Cronbach

After validation of the questionnaire, it was applied to 10 instructors who did not participate in the pre-test, who are responsible for the practical classes and that belong to Senai, José Ignácio Peixoto Professional Training Center, where the study was carried out.

C. Statistical analysis of work

The study group has a total of 20 students, in which each student individually performs manufacturing processes such as lathe machining, milling, and adjustment to fabricate the pieces proposed by the course. At this stage two students were observed per day for 20 days, and the data collection period was 1 hour and 50 minutes for each student, where a total of 40 samples were obtained. The activity developed by the students at the time of data collection is a specific task of the course in question.
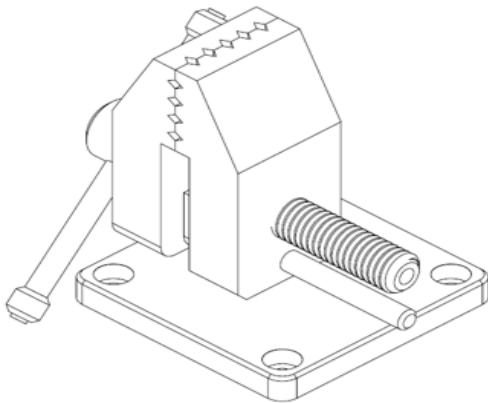

Fig. 2 – activity performed by students

During the development of the task, the student was observed in each 2-minute period, identified which activity the student was performing at the exact moment and classified into the following variables: work, reading of drawing, material search, movement, wait for attendance of the instructor, relaxation or conversation, cleaning and reworking.

D. Chronoanalysis

After the step described in the previous item, a timing of the student's actions was performed, where the time of each action was recorded during the accomplishment of the practical task. The observation time of each student followed the pattern of the previous item. To record the times, the google task timer tool was used. Then, for the purpose of calculation, the data regarding the number of shares and the time of each action were transferred to the table prepared by the author himself using the Excel 2013 software Based on the data obtained, the students' actions were classified in the following values: aggregate, non-aggregate and incidental. Being:

Adds: Adds knowledge to student learning.

Do not add: It does not add knowledge to the student's learning.

Incidental: It does not add knowledge to student learning, but it is necessary for other elements to be realized.

E. Diagram of spaghetti

In this phase, we performed the spaghetti diagram with the intention of identifying and quantifying the students' movement at the time of the practical classes. For this, the layout printed an A4 sheet of the machine shop was used, contemplating all existing machines and equipment.
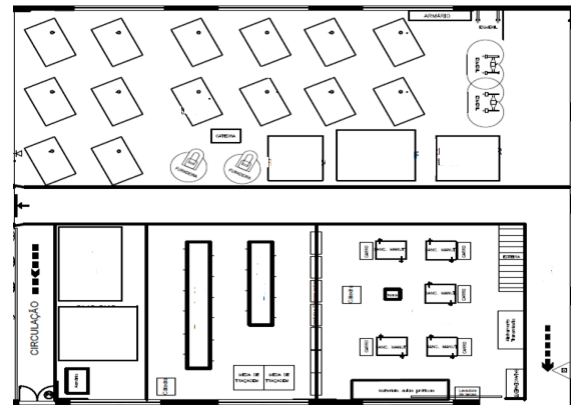

Fig. 3 – layout of the mechanical workshop

Where at first it was manually drawn all the way traveled by the student. The observation time of the students followed the pattern described in the previous item. Then the Paint.Ink software was used to digitally reproduce the path traveled, obtaining the spaghetti diagram. In order to obtain the distance traveled and the number of steps of each student, a pedometer of the brand Omron, model Hj-321 was used.

F. Continuous improvement

After data collection and analysis, it was determined through the problem solving of the A3 report, the implantation of a support of tools in all the mechanical lathes. The device was manufactured with plates of wood 10 mm of thickness, contemplates the tools and instruments most used in the machine.
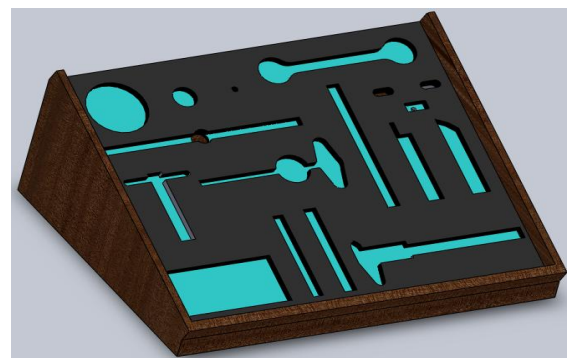

Fig.4 - Tool holder

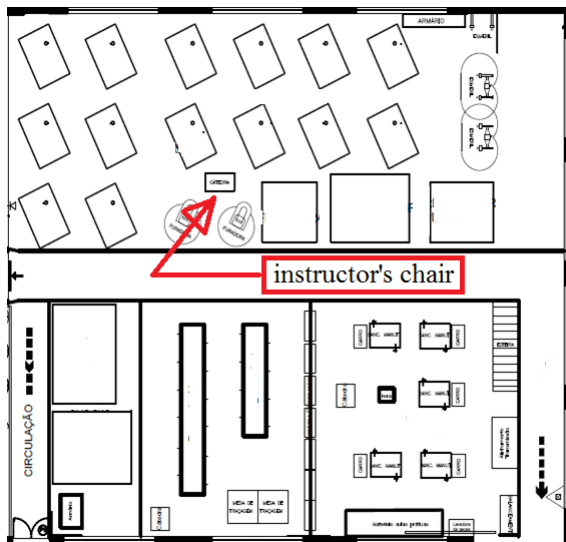which were previously stored in the instructor's chair.

Fig.5 – Location of instructor chair

Mechanical lathes were removed from the mechanical workshop due to lack of replacement parts, non-compliance with the Norma Regulamentadora NR12 of the Ministry of Labor and Employment and precarious operating situations. It was developed and implemented by Senai's technical team, a new physical arrangement of the mechanical workshop.
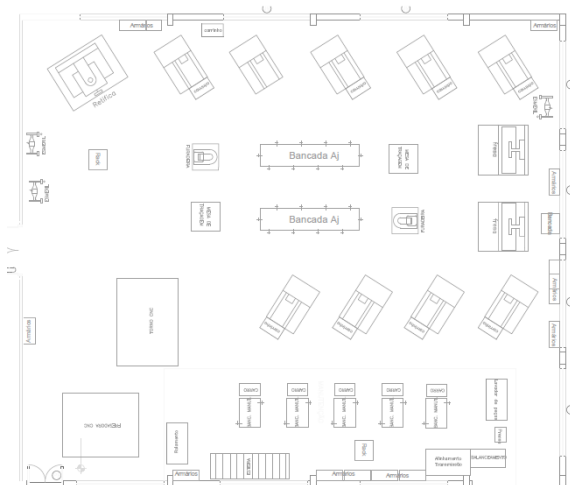

**Fig.6 - new Mechanic workshop layout**

After changes, a new analysis was carried out by placing a led lamp on the machine where the data was collected in order to request the presence of the instructor when the instructor was on, thus reducing the student's movement in the search of the instructor. In addition to creating standard operating procedures for the use of the machine shop and the operation of machines specifically for the development of this work.

To verify the results, we performed a significance analysis with the data collected in the sampling after the application of the methodology, where h0 was classified as the null hypothesis and h1 antagonistic to the null hypothesis.

IV. RESULTS AND DISCUSSION

A. Results of the survey by questionnaire

When applied to the 10 instructors of the unit of study, the values presented in graph 1.
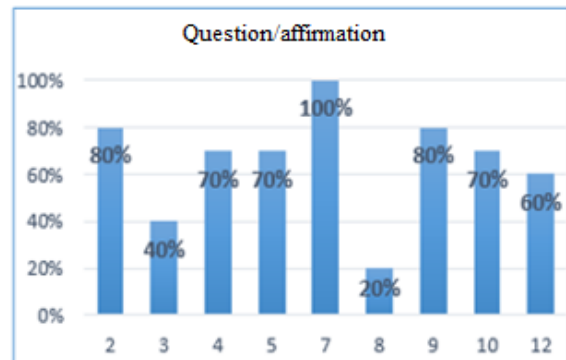

Graph 1 – Questionnaire result

Based on the data obtained by the questionnaire, it was identified the possibility of the reduction of wastes existing in the practical classes of the course in question. Through the questionnaire validation process a value of 0.8759 was obtained for Cronbach's alpha coefficient. All instructors acknowledge the student's over-processing, with 80% saying that the execution of excess processes does not bring value to the learner's learning in terms of knowledge. The repetition of processes, often occurs due to student failure and insecurity in the execution of the task, this denotes the need to improve the student's actions during the execution of the tasks, since 80% of the instructors agree that it is possible to reduce of this index.

B. Results of the statistical analysis

In the first data collection, described in item 2.2, data were obtained in which graph 2 was elaborated, where it is possible to observe the total percentage of the class in relation to the observed variables.
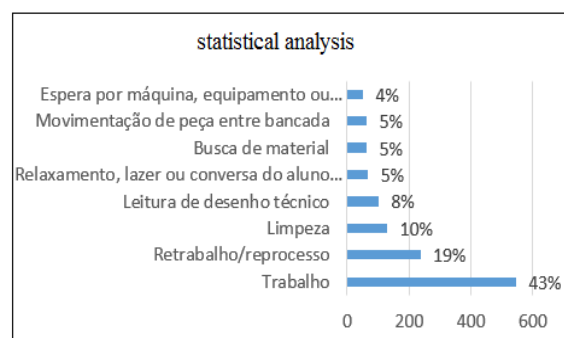

Graph 2 – Statistical analysis

It is noted that 8% of the students' actions are reading technical drawing. What specifically for this analysis is considered as incidental activity. In a total of 1260 items made by the class, only 546 represent the variable work, that is, only 43% of the elements performed are productive. This index indicates the need for an improvement in practical classes, since more than half of the students' actions are considered unproductive.

C. Chronoanalysis results

Through the chronoanalysis, a total of 3176 actions were performed by the class during data collection. Graph 3 exposes the percentage and time of items ranked in the aggregate, non-aggregate, and incidental values.

It is verified that 55% of the actions of the students are classified as non-aggregate, consume a total of 41 hours 21 minutes and 8 seconds, that is, more than half of the total time and quantity of the items are non-productive elements that do not benefit the students' learning. Therefore indicating the need to reduce such indices.

Of the total number of actions taken by the class, 24% are incidental actions that occupy 11 hours 38 minutes and 46 seconds. The number of incidental actions approximates twice as many actions that add value, again indicating the need to reduce these values since the incidental actions also add value to the student's knowledge.
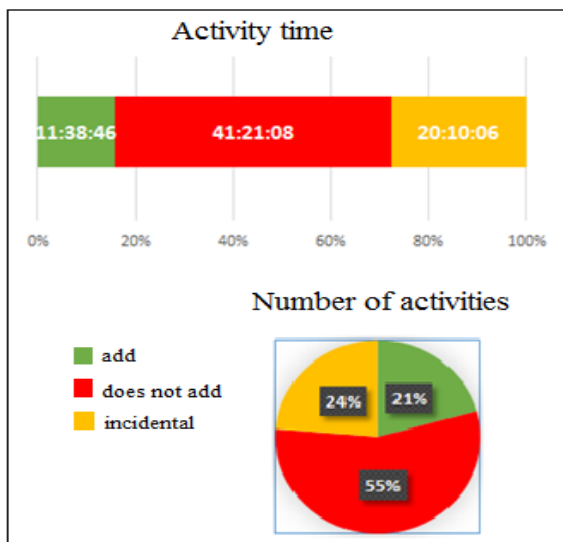

Graph 3 – Chronoanalysis results

The activities that add value to the student, occupy only 21% of the amount of actions contemplating a total of 11 hours 38 minutes and 46 seconds. These values reinforce the results found in Results of the statistical analysis

Among the 3 classifications, the aggregate variable obtained the lowest result, pointing out the need to improve the execution of the tasks.

D. Comparison analysis

Retraining the data after the applied methodology described in item 2, an improvement in the performance of the students was identified.
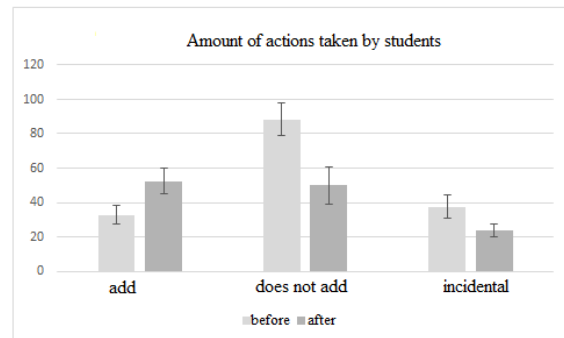

Graph 4 – Amount of actions taken by students

It was achieved a reduction of 6% in incidental activities and a reduction of 18% in the elements that do not add value to the student's knowledge. In activities that add value, an increase of 19% was obtained with a time of 12 hours 6 minutes and 16 seconds. This indicates that the applied methods have had an effect with positive results in terms of productivity.
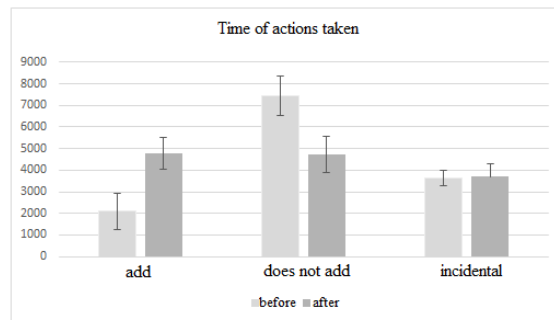
Graph 5 – time of actions
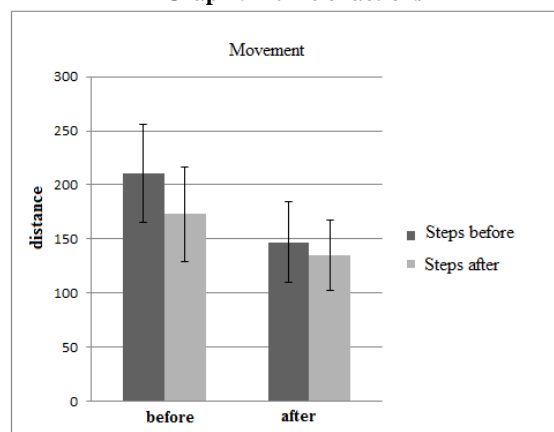
Graph 6 – Movement

E. Movement

The class carried out a total of 4210 steps traveling a distance of 3455 meters, bringing an average of 210 steps and 172 meters per student. These values express a great movement, since the

observation time was 220 minutes per student and the mechanical workshop contains 300 meters².

The following image demonstra o diagrama mais crítico dentre os alunos, no qual o aluno efetuou 289 passos percorrendo uma distância de 240 metros.
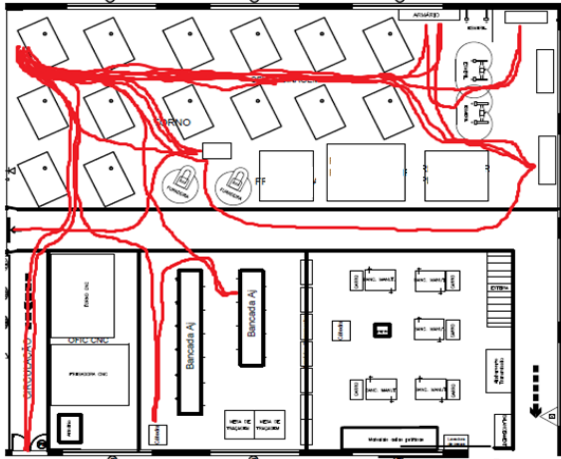

Fig. 7 - Critical spaghetti diagram

The spaghetti diagram of the same student is then presented after the methods are implemented. It is possible to identify a cleaner diagram due to reduced movement, a reduction was achieved specifically for this student of 70 steps and 42 meters, that is, reduced by 25% in the number of steps and 22% in the distance covered. Already the class obtained a total reduction of 755 steps and 242 meters covered.

Fig. 8 diagram of spaghetti after changes

F. Significance analysis

Through the analysis of significance, it was identified which elements actually took effect due to the implanted alterations. It is possible to observe that the changes had an effect on student movement, where the P value was equal to 0 for the correlations. Regarding the number of actions, positive results were obtained in the aggregate classification, that is, the efficiency of the methods to increase such index

was proved. However, the modifications were not enough to reduce the number of actions that do not add value and incidental, this indicates that there is still need to implement another method to reduce this index.

In relation to the time of actions, the analysis shows an insufficiency of the methods adopted to increase the time of actions that add value and reduce the time of the incidental actions. Where it was obtained respectively through the correlations P value 0.049 and value P 0,205. Therefore, changes other than those implemented in order to achieve positive results in this index are necessary. However, it was possible to reduce the time of actions that do not aggregate, obtaining a value P 0.009 thus proving the efficiency of the modifications made.

V. CONCLUSION

The present work sought to identify, quantify the wastes existing in the practical classes of the learning course in maintenance mechanic of a technical school in the Zona da Mata, Minas Gerais, to propose a reduction of the same through the application of Lean Manufacturing methodology.

Through the collection of data, it was identified that 55% of the actions of the class during the activities are activities that do not add value to the student's knowledge and learning. It was also identified that, on average, each student traveled a distance of 172 meters during a period of 220 minutes of class. With the application of the Lean tools, new values were obtained, in which the time from actions that added value was increased by 94%, the time of actions that did not add value was reduced by 42%, a reduction of 30% in number of steps in the class and 22% in the distance covered during class.

Number of shares			
Correlation	P value	h0	h1
Add before X after	0,276	The changes made were enough to increase the amount of actions that	The changes made were not enough to increase the amount of actions you add
Do not add before X after	0,276	The changes made were enough to reduce the number of actions that do not add	The changes made were not enough to reduce the number of actions that do not add
Incidental before X after	0,303	The changes made were enough to reduce the number of incidental actions	The changes made were not enough to reduce the number of incidental actions

Fig. 9 – Number of shares

Moviment			
Correlation	P value	h0	h1
Steps before X after	0	The changes made reduced the number of steps	The changes made did not reduce the number of steps
Distance before X after	0	The changes made reduced the distances covered	The changes made did not reduce the distances

Fig. 10 – Movement

Stock time			
Correlation	P value	h0	h1
Add before X after	0,049	The changes made were enough to increase the action time that it adds	The changes made were not enough to increase the time of the actions that it adds
Do not add before X after	0,009	The changes made were enough to reduce the time of actions that do not add	The changes made were not enough to reduce the time of actions that do not add
Incidental before X after	0,205	The changes made were enough to reduce the time of incidental actions	As mudanças realizadas não foram suficientes para reduzir o tempo das ações incidentais

Fig. 11 – Stock time

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