https://doi.org/10.47456/bjpe.v9i2.40557

Brazilian Journal of Production Engineering
BJPE - Revista Brasileira de Engenharia de Produção
Disponível em: https://periodicos.ufes.br/bjpe
ISSN: 2447-5580
Campus São Mateus
UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO

ORIGINAL ARTICLE OPEN ACCESS

ANALYSIS OF A WORKSTATION IN AN AGRICULTURAL EQUIPMENT FACTORY: STUDY OF MOVEMENT AND LAYOUT

ANÁLISE DE UM POSTO DE TRABALHO EM UMA FÁBRICA DE EQUIPAMENTOS AGRÍCOLAS: ESTUDO DA MOVIMENTAÇÃO E LAYOUT

ANÁLISIS DE UNA ESTACIÓN DE TRABAJO EN UNA FÁBRICA DE EQUIPOS AGRÍCOLAS: ESTUDIO DE MOVIMIENTO Y DISTRIBUCIÓN

Katiucya Juliana Rodrigues de Lima [1] & **André Alves de Resende** [2*]

[1 2] Universidade Federal de Catalão, Faculdade de Engenharia

[1] katiucyal@gmail.com [2*] aaresende@gmail.com

ARTICLE INFO.

Received: 22.03.2023
Approved: 18.04.2023
Available: 03.05.2023

KEYWORDS: *Movement; Layout; Productivity; Material Flow.*
PALAVRAS-CHAVE: Movimentação; Layout; Produtividade; Fluxo de Materiais.
PALABRAS CLAVE: *Movimiento; Diseño; Productividad; Flujo de materiales.*

***Corresponding Author: RESENDE, A. A., de.**

ABSTRACT

The work environment must facilitate and favor the realization of the activities, in order to generate productivity and efficiency. Therefore, the purpose of this study is to analyze the worker's flow and movement at a welding station of an agricultural equipment factory, based on time study and layout. The main objective is to minimize the unnecessary movement and time spent on the daily activities of this workstation. It is an applied research project, descriptive and qualitative. To be developed, the Sequence of Events was considered, where the transport activities were identified and analyzed through the From-To Chart, Relationship Chart and Proximity Diagram, besides concepts of layout and material flow. Some modifications were suggested on the display of storage locations and through simulation because it was verified that the changes would apply on traveled distances and time decreases, meeting this study purpose. The comparison between the current scenario and the proposed one was made, showing the possible gains for the company and demonstrating the importance of studies like these insides of the organizations.

RESUMO

O ambiente de trabalho deve ser um lugar propício e que facilite a realização das atividades laborais, a fim de melhorar a produtividade e eficiência. Assim, este estudo tem como propósito analisar a movimentação do trabalhador em um posto de solda de uma fábrica de equipamentos agrícolas. O objetivo é minimizar as movimentações desnecessárias e o tempo gasto para a realização das tarefas diárias dessa estação de trabalho. É uma pesquisa aplicada, de caráter descritivo e qualitativo, e para sua realização, levou-se em consideração a sequência de eventos do posto de trabalho. As atividades de transporte foram identificadas e analisadas através da Matriz "de-para", Matriz de Relacionamento e Diagrama de Proximidade, além de conceitos sobre layout e fluxo. Foram sugeridas mudanças na disposição dos estoques, e através de simulação, verificou-se que elas acarretam em diminuições na distância percorrida e no tempo gasto, atendendo os objetivos do trabalho. A comparação entre o cenário atual e o proposto foi realizada, exemplificando os possíveis ganhos para a empresa, e, comprovando a importância de estudos dessa natureza dentro das organizações.

RESUMEN

El ambiente de trabajo debe ser propicio y facilitar la realización de actividades laborales para mejorar la productividad y la eficiencia. Por lo tanto, este estudio tiene como objetivo analizar el movimiento del trabajador en un puesto de soldadura en una fábrica de equipos agrícolas. El objetivo es minimizar el movimiento innecesario y el tiempo empleado en las tareas diarias de esta estación de trabajo. Es una investigación aplicada, de carácter descriptivo y cualitativo, y para su realización se consideró la secuencia de eventos del puesto de trabajo. Las actividades de transporte se identificaron y analizaron a través de la matriz "de-para", la matriz de relación y el diagrama de proximidad, así como conceptos de diseño y flujo. Se sugirieron cambios en la disposición de los stocks y, a través de simulación, se demostró que estos cambios resultan en reducciones en la distancia recorrida y el tiempo empleado, cumpliendo con los objetivos del trabajo. Se realizó una comparación entre el escenario actual y el propuesto, ejemplificando los posibles beneficios para la empresa y demostrando la importancia de estudios de este tipo dentro de las organizaciones.

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

1. INTRODUCTION

Due to the concern with productivity, compatible organizations are seeking to improve working conditions, adding the most modern resources available in the market, technologies, and skilled labor with the company (Prates, 2007). This apprehension with levels of control began in the first decades of the twentieth century, when Taylor used concepts through Scientific Management, addressing the benefits of observing and studying work processes (Villarouco & Andreto, 2008).

According to Barnes (1977), Taylor was the pioneer in facing questions about the best way to perform tasks, and the evolution of these questions gave rise to the study of times, a tool that can be used to increase the efficiency of the factory (Barnes, 1977). Still for the same author, concepts of analysis of the deceased worker's movements with the studies of Frank and Lillian Gilbreth, who gathered knowledge of engineering and psychology, and studied fatigue, monotony and the development of techniques such as the process flow chart, the study of micro movements, among others.

Over the years, the industry became convinced that the study of times and motions are complementary and the tools must be applied mutually in a company to solve problems (Barnes, 1977). After all, the study of times and movements contributes to the analysis of work, and aids with the creation or alteration of systems, with the aim of increasing productivity, efficiency and reducing costs (Santos et al., 2013).

This study is important, since the work environment should favor the good performance of activities, as it will directly reflect on productivity and can impact the company's profitability (Prates, 2007). Some conditions favor the work environment, such as the arrangement of equipment in a logical production sequence, adequate lighting levels, minimum necessary distances between machines, areas destined for waste and necessary places for breaks, among others, bringing greater motivation and quality of life to the worker (Fiedler et al., 2009).

In the agricultural industries sector, for example, since the appearance of agricultural machines and implements, there has been technical evolution and growth in the offer of equipment that optimize productivity in the field, and that use increasingly advanced technologies. The industry in this sector then had to focus its efforts on technological innovation to be competitive in the market (Vian & Junior, 2013). When it comes to competitiveness, Brazil loses to several countries, finding itself in 59th place in 2022, among 63 economies analyzed, following among the least competitive nations in the world (Riveira, 2022).

Based on the above, the objective of this work is to analyze a welding job for a sugarcane harvester feed component, in an agricultural machinery factory, through movement metrics, and considering its productive resources, physical arrangement and evaluating their performance based on the work environment and limitations.

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

2. LITERATURE REVIEW

It can be considered that determining the standard time for a haircut in a beauty salon, or the preparation of a sandwich in a fast food chain, has become common these days. This type of analysis crossed the boundaries of the industry. After all, the productivity of an employee and the quality of his service can be measured, and thus determine his permanence in an organization that competes in the market for profitability (Peinado & Graeml, 2007).

The study of the operation through times, movements and methods aims to eliminate the unnecessary movements of the worker, and find a more efficient way of carrying out the daily activities, and in this way, the company seeks to reduce costs and increase productivity (Peinado, & Graeml, 2007) without neglecting the importance that human resources have for the performance of tasks. It is important to define what is expected of the worker in terms of performance and demonstrate the contribution of their activities to the organization (Slack, Chambers & Johnston, 2002). Taylor (2012) states that when the worker has defined the task he must perform and the determined time to perform it, he has a precise measure, and through it he can appreciate his progress throughout the day, then working with greater satisfaction.

One should also consider the impact of carefully planning the workplace, as approximately 20 to 50% of a company's total operating expenses are attributed to material handling (Tompkins et al., 2010). The same authors state that by optimizing the workplace and eliminating unnecessary movements, it is possible to reduce these costs, increase productivity and generate greater satisfaction for those involved.

2.1 Time And Motion Study

The structure of the study of times and movements can be imagined as a funnel, where the analysis starts with the overview of the work and narrows down until it focuses on the detail. First, the production process is analyzed in order to detect the critical points. From this analysis, the process is divided into activities or operations, to finally divide each activity into elements, focusing on those performed by workers (Contador, 2010).

The study of times not only has the purpose of establishing the best way of working, but also to obtain the normal time and the standard time for the accomplishment of each task. Normal time, defined by Contador (2010), is the time required for a qualified and properly trained person, working at a normal pace, to perform a specific task. The same author defined the standard time as normal time plus tolerances for fatigue and delays.

According to Peinado and Graeml (2007), with this normal and standard time information it is possible to find a reference standard that will serve to: determine the company's productive capacity; preparation of production programs; determination of the value of direct labor in the calculation of the Cost of Goods Sold (COGS); estimating the cost of a new product during its design and creation; balancing production and assembly lines.

Although these two techniques emerged separately, at different times, and by different people, they came to be seen as complementary methodologies, and their use in companies happens simultaneously to be completer and more satisfactory (Barnes, 1977).

According to Barnes (1977), companies apply different degrees of importance to these techniques, varying according to their objectives and the current situation of the business. For example, the cost of applying these studies must always consider the expected return on capital, that is, the degree of application and development of techniques within the company may vary according to the potential benefits.

Barnes (1977) presents the procedure for carrying out the time study, which may vary at some level, depending on the company where it will be applied. First, you must obtain and record information about the operation and the operator under study, a sketch of the workplace, which demonstrates the position of the operator, tools, devices and materials. Afterwards, divide the operation into elements and record a complete description of the method, of the step by step that the worker is using to carry out the operation at that moment, in order to carry out an elementary analysis of it. At this stage, a process flow chart can be used, explaining the movements, inspections, waits, storage and modification steps that occur in the production space.

Also, for Barnes once more, one should observe and record the time spent by the operator through timing, and determine the number of cycles to be timed, as the study of times is based on sampling, where the greater the number of timed cycles, the better it will be the result, and the smaller the variability of these measurements, the more accurate the result.

Afterwards, it is necessary to evaluate the pace of the operator, based on the time that the analyst considers normal to execute them. One way to define the pace is to consider the normal operating speed as 100%, and if the analyst considers that the operator is speeding above normal, he will assign a value greater than 100%. Likewise, if you consider that the velocity is lower than expected, the values will be less than 100% (Peinado & Graeml, 2007).

2.2 Organization And Layout

For Stevenson (2001), the layout, or physical arrangement, is the configuration of departments, work centers and facilities and equipment, which emphasizes optimized movement. According to Tompkins et al. (2010), in manufacturing companies, the layout needs to support production and help the organization achieve its goals.

For Tompkins et al. (2010), some objectives of the design of the facilities are: to improve customer satisfaction by meeting deadlines and meeting their needs; increase customer response speed; reduce costs and increase profits; support the organization's vision by improving material handling, control and inventory; efficiently use people, equipment, space, and energy; be adaptable and promote easy maintenance; promote worker safety and satisfaction, as well as energy efficiency and environmental responsibility.

To identify what the work center requires, you need to consider the flow of materials, the relationship between activities, and the space required. The flow of materials considers the production batches, the configuration of the facilities and the layout (Tompkins et al., 2010). According to this author, flow is the movement of materials, information, people, goods and energy through the various processes of the factory. For a flow to occur, an object, a resource and communication are required. The object is what will undergo the action, will be moved from one point to another; the resource is what will carry out this action, which could be a person, or a forklift, for example, and communication is what coordinates this flow, dictating the rules.

A very useful tool for analyzing a flow is the process flow chart. It graphically demonstrates all the steps that occur in a work center, both for raw materials and finished products, which can be operations carried out, transport, waiting, inspections and storage (Sule, 2009).

Each of these activities has a specific symbol to be represented on the graph, and its objective is to find the method that uses the minimum number of symbols. According to the same author, through this analysis, it is possible to optimize the activities and also the layout of the workstation by analyzing, for example, reducing the number of transports carried out by relocating machines in the physical space.

2.3 Methods For Layout Analysis

One of the most used methods is the "from-to" matrix. It shows the number of trips or movements made by a unit between several departments, being a quantitative way of identifying the need for proximity to workstations. Through it, those paths that have the highest number of flows should be as close as possible to minimize the distance traveled (Sule, 2009).

In this matrix, the rows represent the "from", meaning where the flow is starting from, and the columns represent the "to", meaning where the flow is going. The numbers represent the amount of flow, which can be the number of trips made by the operator, or the number of parts transported, etc.

In addition to the aforementioned matrix, it is possible to correlate it with another, the relationship matrix. It demonstrates the need for two departments to be close, or not, based on the analyst's opinion, and can consider the flow intensity, convenience, need to work with the same staff, need for communication, or use the same facilities (Sule, 2009).

After preparing the matrix, it is necessary to graphically represent the importance of the proximity of the links, following a relationship proposed by Muther (1978), where each relationship classification will have a score and a number of traits to be represented graphically.

One of the most used methods is the "from-to" matrix. It shows the number of trips or movements made by a unit between several departments, being a quantitative way of identifying the need for proximity to workstations. Through it, those paths that have the

highest number of flows should be as close as possible to minimize the distance traveled (Sule, 2009).

In this matrix, the rows represent the “from”, meaning where the flow is starting from, and the columns represent the “to”, meaning where the flow is going. The numbers represent the amount of flow, which can be the number of trips made by the operator, or the number of parts transported, etc.

In addition to the aforementioned matrix, it is possible to correlate it with another, the relationship matrix. It demonstrates the need for two departments to be close, or not, based on the analyst's opinion, and can consider the flow intensity, convenience, need to work with the same staff, need for communication, or use the same facilities (Sule, 2009).

After preparing the matrix, it is necessary to graphically represent the importance of the proximity of the links, following a relationship proposed by Muther (1978), where each relationship classification will have a score and a number of traits to be represented graphically.

3. METHODOLOGY

In order to carry out the study, data were collected from the activities carried out at the welding workstation, in order to reduce the movement and time spent by the worker when looking for the parts to be welded. With the help of an engineer and the sector supervisor, both from the manufacturing engineering department, the sequence of events was extracted, which, in addition to the activities carried out at that station, also includes the time spent on them.

This report, the Sequence of Events (SOE), details the operator's activities step by step, covering the stages of assembly, welding, loading, unloading, among others. SOE, as well as the data obtained during the observation of the workstation, served as the basis for the preparation of the "Process Flow Chart", which facilitates the visualization of activities, demonstrates the elapsed times and distances covered and uses symbols to identify the stages of operation, transport, waiting, inspection and storage.

3.1 Layout Elaboration

Through observation and analysis of the work center, it was possible to obtain the exact location of each device, and the location of the stock of each of the parts was identified. Through the use of a CAD software, a layout of the production center was elaborated, representing the physical space in a simplified way. The names of parts, jobs and any other information that could expose the company under study were disregarded.

Based on this layout, a demarcation was carried out related to the movement of people, materials and information in this production center, identifying each of the stocks of parts, checking between which locations there is flow and what distance the operator needs to move, among others information that will be used in the analyses.

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

3.2 Flow Analysis

With the objective of analyzing the flow involved in the process, firstly, the “from-to” matrix was elaborated, in order to visualize where the flow comes from and where it goes, considering the respective intensities, that is, how many trips are made by the worker between points.

With the information, the relationship matrix was also elaborated, indicating the relationship between each of the links, determining where there is greater or lesser flow, and classifying them among A, E, I, O and U.

Through these analyses, it was possible to identify which stocks have the highest flow of operators, that is, those stocks where the worker visits most in order to get the parts needed for welding. Thus, with the use of the mentioned methods, improvements in the disposition of the stock were suggested in order to reduce this excessive movement.

The analysis to suggest improvements began by first identifying the stocks with the highest flow and, as a proposal, these were brought closer to the welding device. After all, the greater the flow, the shorter the distance between the two points should be. For the proposal, the size of the items, weight, availability of space at the workstation and the type of storage that the item needs, being a common or specific rack, were considered.

3.3 Elaboration Of The Proposal

According to the analyzes carried out and the opportunities identified, it was possible to suggest changes in the production center, in order to adapt it to the needs of the operator, reducing unnecessary movements, thus optimizing the activities carried out in this sector in question.

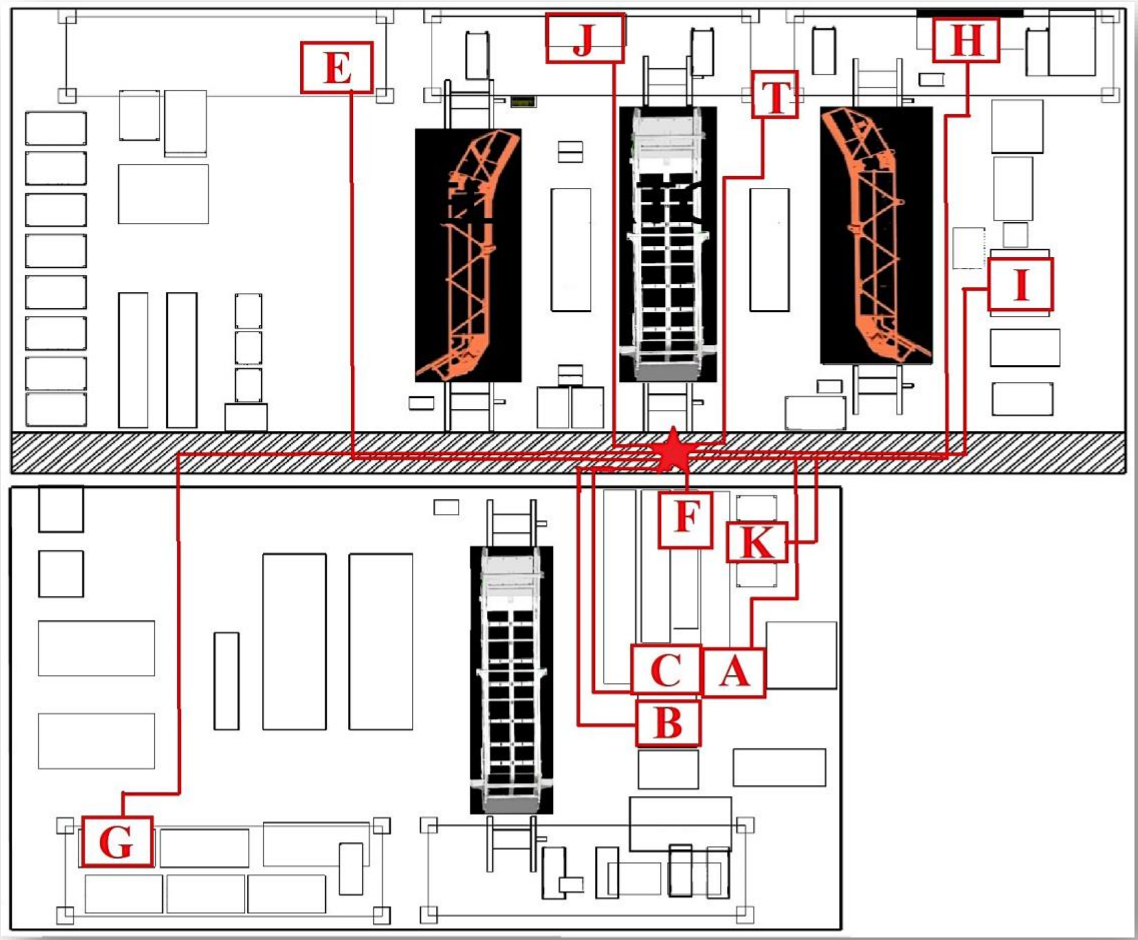
First, the possible changes were minimally analyzed, in order to suggest those that would most result in improvements for the operator and for the process. A simulation was carried out, using photos of the workstation, to demonstrate the current position of the items and their suggested position, in order to facilitate understanding and to clearly exemplify the proposed modification.

A trolley was then designed for the storage of items that proved to be critical, as they are used a lot, and that were stored in an insecure way and without any type of identification. Thus, it was possible to visualize the benefit of implementing the suggested changes, based on the reduction of the distance covered and the time spent on activities.

4. RESULTS AND DISCUSSION

In order to facilitate the understanding of the work, and for a better visualization, the layout of the workstation was designed in a simplified way, and the stock points were randomly named with letters, without identifying the nomenclature used by the company (Figure 1).

Figure 1. Workstation layout with indication of material.



Source: Authors (2023)

The activities characterized as transport are the ones that will be the focus of this study, and this identified movement can be considered in two ways: going from the central welding device towards the parts stocks and also from the stocks to the welding device. This is because the worker leaves his starting point to look for the necessary parts in each of the stocks, and then returns to the starting point, deposits the parts and performs the welding. The starting point is marked with a star in Figure 1 and the stocks considered for the identification of the flows are represented by letters, with the mentioned flow of people and raw materials and welded subassemblies.

This movement takes place inside the welding workstation, being observed frequently between the bench and the welding device, the hoist and the welding device, and between the stocks and the device.

With the stock information, from A to K, considering the hoist with the letter T, the workbench with the letter B, and the worker's starting point with the letter D, Table 1 was prepared, considering the flow of materials between these points. With this, the “from-to” matrix of this process was elaborated, represented in Table 2, where the lines represent the beginning of the flow, where the flow leaves, and the columns represent where it goes. In addition, in Figure 2, it is possible to verify the relationship matrix of this study, where the most critical departments, which need to be located close, receive the letter A, and for the others, as the need decreases, they receive the letters E, I and O. The other calls, which do not need proximity to each other, received the letter U. The relationship matrix demonstrates the need for the departments to approach, and to be understood, it needs to be placed in a matrix, where the letters A, E, I, O U and X represent the relationship levels.

Table 1. Workstation flow intensity.

Item	Process Sequence	Flow Intensity
20	D-A-D	1
21	D-F-D	1
22; 24; 25	D-C-D	7
23; 33	D-E-D	3
27; 28	D-T-D	2
15+14+4; 13+14+4; 16+4	D-B-D	3
29; 32	D-G-D	2
31; 35	D-H-D	4
30	D-I-D	1
34	D-J-D	2
36	D-K-D	2

Source: Authors (2023)

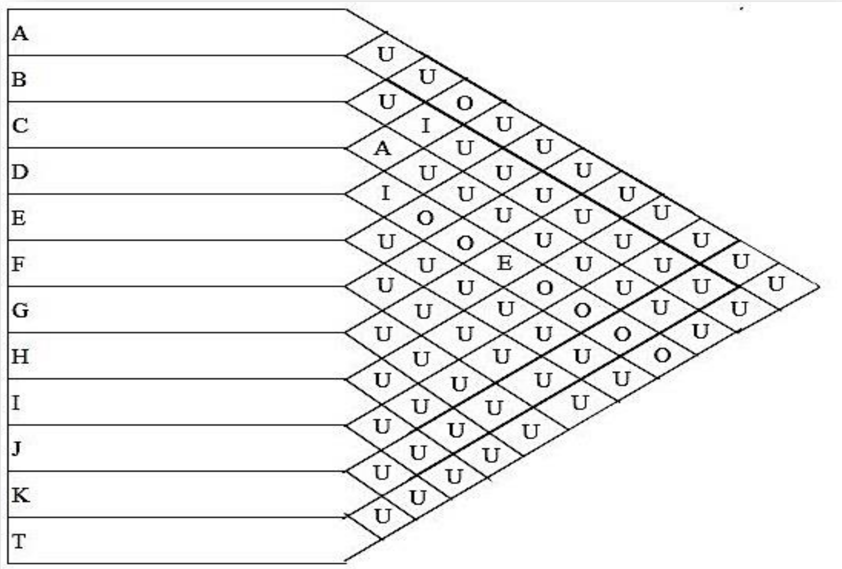
Table 2. “From-to” matrix of the analyzed process.

FROM TO	A	B	C	D	E	F	G	H	I	J	K	T
A				1								
B				3								
C				7								
D	1	3	7		3	1	2	4	1	2	2	2
E				3								
F				1								
G				2								
H				4								
I				1								
J				2								
K				2								
T				2								

Source: Authors (2023)

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

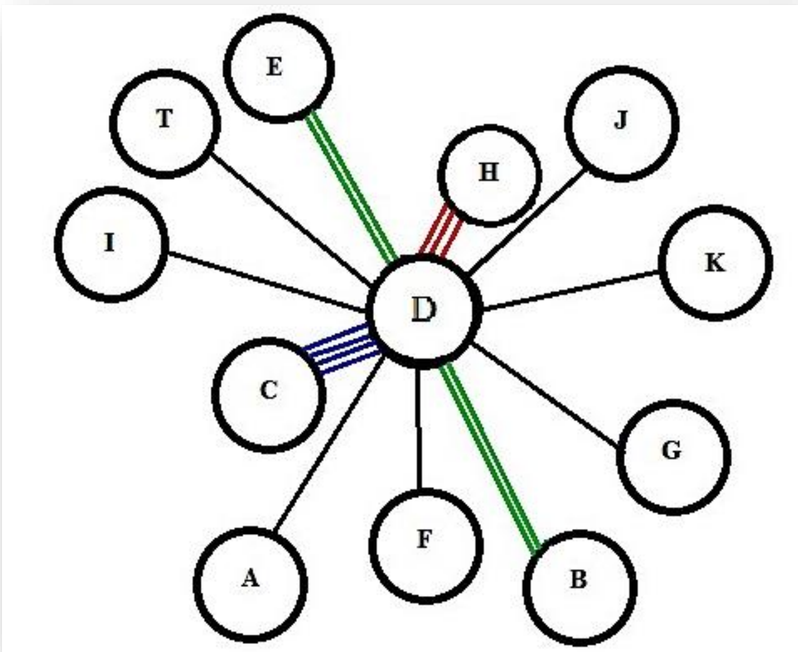
Figure 2. Relationship Matrix.



Source: Authors (2023)

Through the relationship matrix, it is possible to draw up the Proximity Diagram, as shown in Figure 3, which graphically represents the relationships. The relations that received “A” are linked with four dashes; those classified as “E” receive three dashes; those classified as “I” received two dashes; those given “O” are linked by a dash; “U”, no connection, therefore, no dashes.

Figure 3. Proximity Diagram.



Source: Authors (2023)

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

Through the "from-to" and relationship matrices, it is possible to observe where the greatest number of trips by the operator takes place, object of analysis in this work, being characterized as greater flow. Therefore, the highest flow is observed between D and C, with 7 trips, followed by D and H with a flow of 4. These flow values were categorized as high for the purposes of this analysis. Flows equal to 3, between D and E, and between D and B, were classified as medium, and the flow between D and T, D and G, D and J, D and K, can be considered low, with 2 trips, followed by the flows of only 1 trip, between D and A, D and F, and D and I.

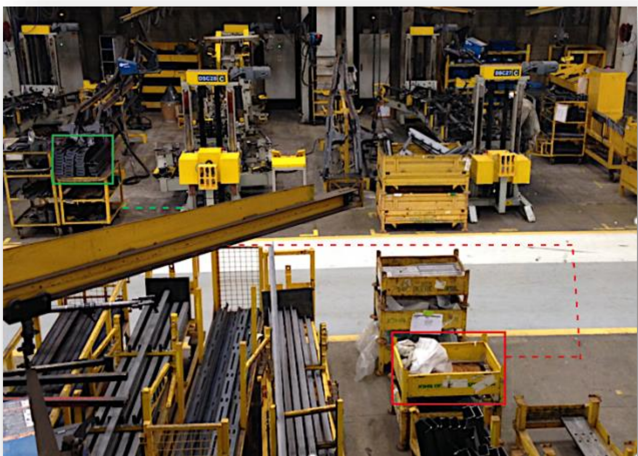
With the analyzed data, and preserving the purpose of guaranteeing a shorter movement distance for the worker, it is possible to approximate the stations with greater flow intensity, and avoid the cross flow between them, proposing a rearrangement of the workstation stocks.

Based on the results of the analyses, changes in the stock were suggested for the most critical cases, which are stock C, with the greatest flow of people, and stock G, which, despite having a flow considered low, has the greatest distance to the welding location. With the strategic location of these two warehouses, gains in terms of time and productivity are already expected. All changes were proposed based on having enough stock to service 4 machines, which is the maximum amount allowed per shift.

4.1 Proposal For Stock C

Stock C, identified with the highest number of trips made by the worker, is currently located in the lower right section of the layout, just after the aisle. Items 22, 24 and 25, stored there, are large, both in length and weight and, precisely because of this, it becomes impractical for the operator to cross the aisle to pick them up. Therefore, it was proposed to place the stock of these items on the left side of the welding device, on a cart. The current position of the stock and the proposed location are shown in Figure 4, the current position being represented in "red" and the proposal presented in "green".

Figure 4. Current stock position (red) and proposed position (green) for C stock.



Source: Authors (2023)

For the relocation of these items, an informal conversation was held with the operator who performs the activities of this workstation in the first shift, who reported that the normal racks, where the parts are currently accumulated, are not ergonomic enough or even practical. The pieces are placed without any order, and the size of the trolley does not support its entire length, thus leaving the ends outside the trolley. This makes handling dangerous, as if someone bumps into any of the pieces, several of them could be knocked over, causing an accident at work.

Therefore, considering this report, the elaboration of a special rack was proposed, that is, specific for the items in question. Figure 5 illustrates the scenario that was proposed virtually for the arrangement of items. With the proposal, both the supply of parts and their removal is facilitated by the organization and their arrangement in the cart, which was made with the proper divisions for the items.

Among these, item 24, green color in Figure 5, presents the largest number of parts to be sought, a total of 9, and according to the 16kg limit imposed by ergonomics, the worker can only carry the amount of two of these parts at a time, thus respecting the weight and ensuring safety during the execution of the work. These items were placed on rods, allowing them to remain horizontal, suspended by one of the holes in the piece itself. In this way, the supply of parts on the trolley, and their removal by the worker, will be facilitated, as the part will slide. Items 22 and 25, blue and red in Figure 5, are used once per machine and arranged at the top of the cart, in separate locations.

Figure 5. Cart proposed for items 22, 24 and 25.

Source: Authors (2023)

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

Items 24, 25 and 22 can readily be allocated to this rack, which has been fully adapted for the process, paying attention to their arrangement in an organized, standardized and identified manner, reducing the chances of raising doubts and extending the search time even further.

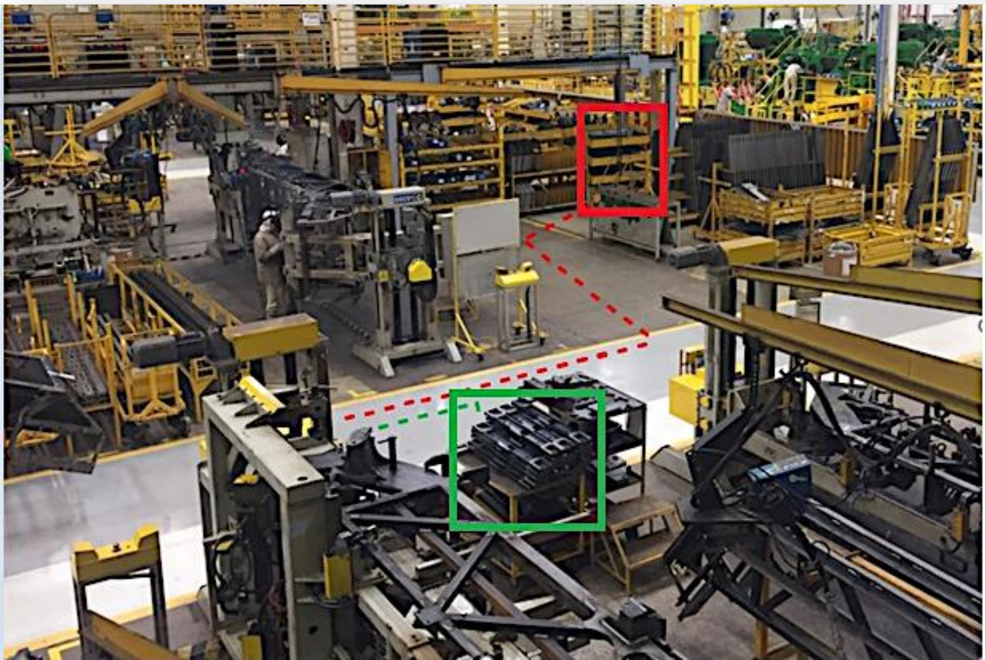
4.2 Proposal For Stock G

Stock G is considered critical due to its location in the lower left part of the layout, with the greatest distance from the welding device. In addition, it is on the opposite side of the corridor, making the worker's path difficult for other pedestrians, forklifts and even supply carts arriving.

For the items in this stock, the suggestion was to create a tray on the same cart mentioned for stock C, seen in Figure 5, which will house the parts in question and allow the worker to fetch the parts from the stock just once in the beginning of your work shift. Also, load the trolley with the amount you will use during the shift's production. In Figure 5, the items are represented by the color purple.

The previously mentioned device has already been planned to hold the necessary quantity and the appropriate size of items 29 and 32, which are more than 1 meter long, and it contains the dividers with the correct spacing for separating the parts, all with the correct identification of the item number, to avoid confusion when finding them. With this, the G stock will also be located next to the welding device, eliminating the need for the worker to walk a long distance and need to cross the corridor. The comparison between the current scenario and the proposed one is shown in Figure 6, where the movement in red symbolizes the current one and the one in green represents the proposal.

Figure 6. Movement in the current (red) and proposed (green) scenario for stock G.



Source: Authors (2023)

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

4.3 Proposal For Other Stocks

Stock H, currently located in the upper right corner of the layout, as shown in Figure 1, needs to be brought closer to device D, because with the number of trips the operator makes to this stock, he loses a large fraction of time at the end of the day. Therefore, the suggestion is that the H stock items be located on the left side of the welding device, in small KLTs (modular plastic boxes), on a cart that already exists on site.

This suggestion is given because items 31 and 35 of stock H are small and easily fit in small and medium KLTs. With this, one of the trolley shelves can be organized to have two KLTs with each of the items separately, optimizing the space near the device where they are used.

Now considering the stocks with a flow of three trips by the operator, stocks E and B, it is seen that stock B, as it is also a bench for welding small items, its movement is more restricted, and because it is used for other processes, it chose up for keeping her in the same place.

Items from stock E, 23 and 33 will be moved to stock J, with part 34, on their own currently used KLTs, decreasing the distance traveled. Both stocks contain small items, and some of them, like 33 and 34, are used in the same part of the process, allowing the items to be loaded together in just one trip, being within the weight limit allowed for carrying by the worker.

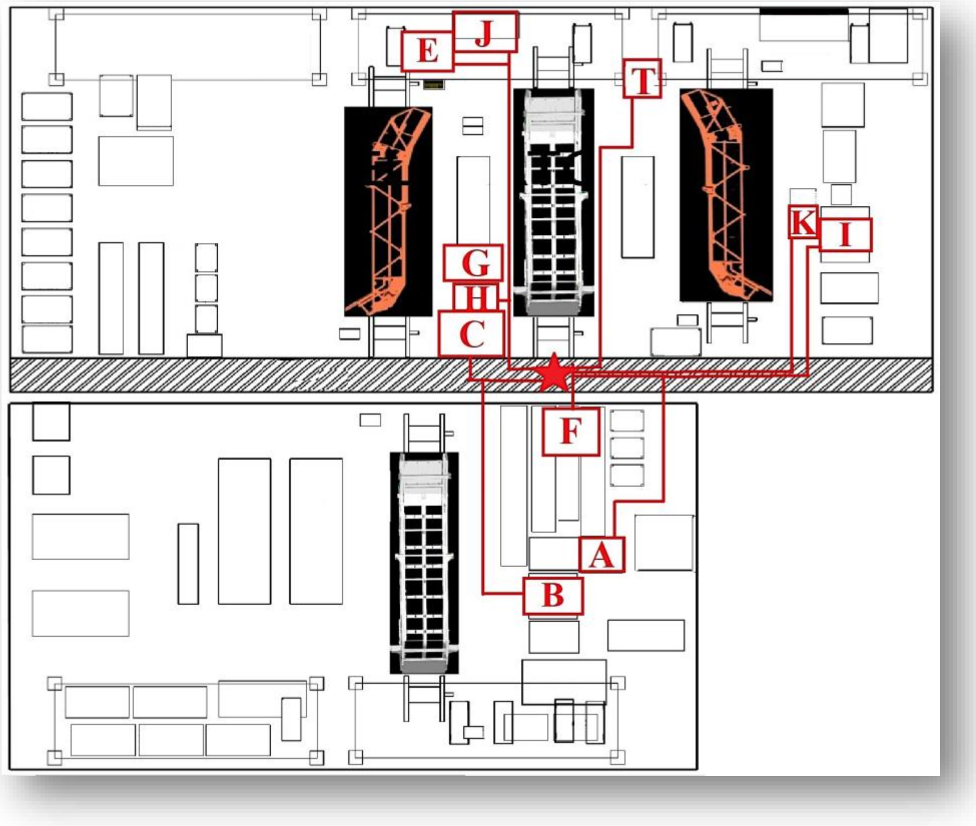
For stocks with a flow of 2 trips, K and T, the hoist has a fixed structure in the production center, which is then kept there. Item 36 of the K stock is a heavy item, and its location after the aisle hinders the operator's movement. Therefore, stock K was proposed alongside stock I, removing the need for the operator to cross the aisle, and the item's dimensions call for a floor container to stock it.

For stock items with only one operator trip, A, F, and I, it is seen that items 20, 21 and 30 of these stocks are large and of very high weights, therefore, their location will be kept where it is currently located, after all, they demand a large storage space, and this area is not available elsewhere.

The final layout, covering all the proposals mentioned above, is shown in Figure 7, and demonstrates the new worker movement flows.

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

Figure 7. Proposed layout for the analyzed workstation.



Source: Authors (2023)

4.4 Evaluation Of The Presented Proposal

The results proposed here had their results measured considering the impacts on the distance traveled by the worker and, consequently, on the time spent to perform such tasks. The distances between stocks and the welding device were measured, for the before and after, and a simulation was performed using the distance and considering the weight of the items, to identify the variation in the time spent in each of the displacements. The results of the distance traveled before and those expected after, as well as the times, are presented in Table 3, for the items whose location was modified.

Table 3. Comparison of current and proposed distance traveled.

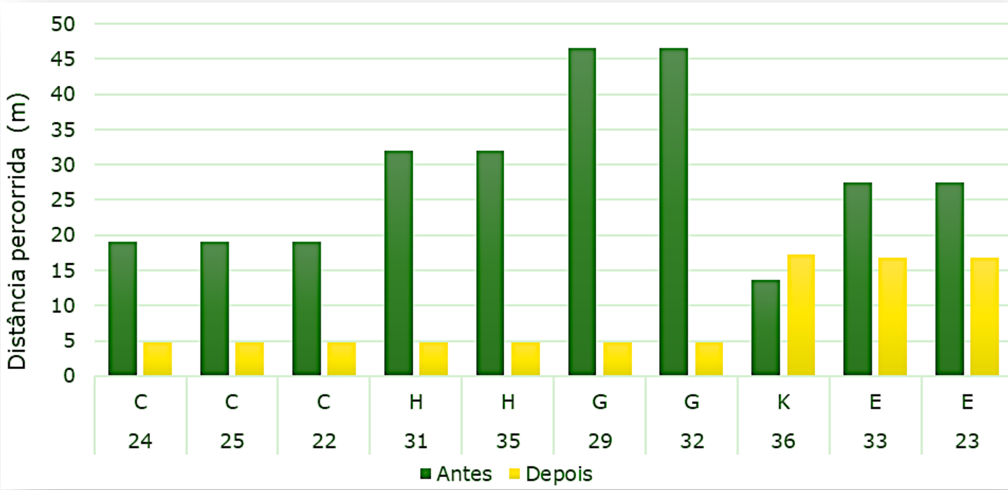
Item	Stock	Distance traveled before (m)	Distance traveled after (m)	Percentage change in distance	Time before (s)	Estimated time (s)	Change Percentage of time
24	C	19,13	4,72	-75,33%	71	42	-40,85%
25	C	19,13	4,72	-75,33%	27	12	-55,56%
22	C	19,13	4,72	-75,33%	25	11	-56,00%
31	H	32,03	4,72	-85,26%	44	17	-61,36%
35	H	32,03	4,72	-85,26%	35	8	-77,14%
29	G	46,54	4,72	-89,86%	61	17	-72,13%
32	G	46,54	4,72	-89,86%	52	22	-57,69%
36	K	13,72	17,32	26,22%	58	68	17,24%
33	E	27,40	16,80	-38,69%	38	26	-31,58%
23	E	27,40	16,80	-38,69%	35	23	-34,29%

Source: Authors (2023)

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

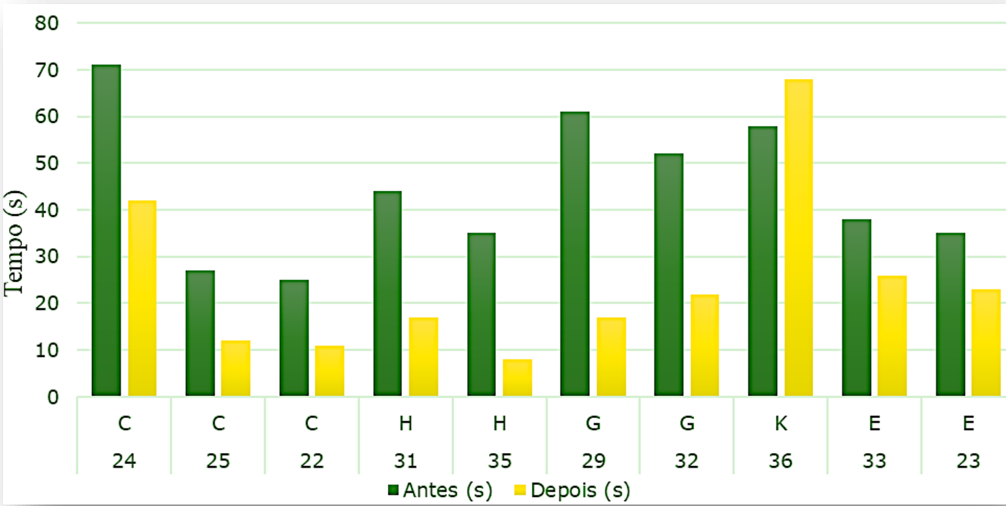
The data were placed in a comparative graph, showing the expected variation in the distance covered, which can be seen in Figures 8 (in relation to distance) and 9 (in relation to time).

Figure 8. Comparison graph of distances currently covered (before) and estimated (after).



Source: Authors (2023)

Figure 9. Comparison graph of current (before) and estimated (after) times.



Source: Authors (2023)

It is possible to observe that most of the suggestions arose from significant decreases in distance and time spent by the operator in carrying out these movements, and only for item 36 the proposed changes had unfeasible results, with the increase in distance and time spent. As the purpose of the study was to reduce time and distance, changes to this item were disregarded in the other calculations, prevailing for him the distance and time equal to the initial one.

Thus, the sum of the current time results in 388 seconds to carry out the activities described here, and the estimated time based on the changes was 178 seconds, showing a variation of 210 seconds, considering values for the production of 1 machine.

"Difference between times=388-178=210 seconds"

Assuming that next year's production is forecast at 600 machines, dividing by 12 months results in 50 machines per month. Multiplying the time savings value of 210 by 50 machines, the total time savings per month is 10,500 seconds, or 2 hours and 55 minutes less per month than the worker would spend at this work center.

(Time saver)⁄(month=210x50=10,500 seconds)

With this decrease in time spent, there may be an increase in the worker's productivity rates, according to the company's metrics, and, in addition, with the time available, he can perform other activities, training and studies.

5. FINAL CONSIDERATIONS

Organizations often find opportunities to improve their process more and more, through small changes in routine activities. Observing if the worker moves too much, and checking this movement in more depth, is a way to check if the process is efficient. It is also necessary to analyze whether it is possible to reduce the distances covered, optimize the time spent, make changes to the environment in order to organize it in a more favorable way for the development of activities.

For these analyses, it is feasible to use concepts from the study of times and movements applied in conjunction with the theories of layout and movements, as was done in this work, making it possible to analyze and understand the importance of these concepts, in order to reduce unnecessary movements in a production center.

With the application of concepts and methods in the study area, it was possible to simulate a decrease of 2 hours and 55 minutes per month, for the development of activities in the analyzed workstation, through the change of positioning of critical stocks for the process, leading to considering the size of the items, the weight and the type of accommodation most suitable for them.

In this way, the objectives of the work of analyzing the current workstation, verifying the movement and time spent in the process stages, and proposing ways to optimize the physical space, were achieved. Through them, worker productivity levels were verified, as well as the benefits that this improvement could bring.

In order to further benefit the company and the worker, it is possible that a continuation of this study will be carried out in the future, and that it may encompass all the other stages of the production process, which were not considered in this work due to deadlines for study and realization. The process carried out on the sides of the item, for example, as mentioned at the beginning of the work, also has the potential to be studied, since the process requires the worker to move to fetch parts for welding, also in these cases.

Citation (APA): Lima, K. J. R., de. & Resende, A. A., de. (2023). Analysis of a workstation in an agricultural equipment factory: study of movement and layout. *Brazilian Journal of Production Engineering,* 9(2), 27-44.

In addition, it is possible to extend this study to the other stations of the company, such as assembly, the primary sector where the plates and tubes are allocated, the warehouse where the materials that will be used come from, as it is an applicable tool in any environment.

This project brought up aspects that are often forgotten in organizations, such as the time that workers are spending on parts of the process that will not add value to the final product. In the case studied, it is noticeable that the worker is only productive and generates value when he is welding, and not when he is moving around the work center.

This study also demonstrated that the optimization of production processes is possible, in a simple way, not only through the investment of large amounts or the mobilization of a large number of people but, rather, through accessible and tangible changes and with low cost for the corporation.

References

Barnes, R. M. (1997). *Estudo de movimentos e de tempos: projeto e medida do trabalho*. 6 ed. São Paulo: Edgar Blücher.

Contador, J. C. (Coord.) (2010). *Gestão de operações: Engenharia de Produção à serviço da modernização da empresa*. 3ª ed. São Paulo: Edgard Blücher LTDA.

Fiedler, N. C., Wanderley, F. B., Nogueira, M., Oliveira, J. T. S., Guimarães, P. P., & Alves, R. T. (2009). Otimização do layout de marcenarias no Sul do Espírito Santo baseado em parâmetros ergonômicos e de produtividade. *Revista Árvore*, 33(1), 161-170.

Riveira, C. (2022). Brasil cai duas posições e é 59º em ranking de competitividade global. Veja as lições para o país. *Revista Exame*. Recuperado de: https://exame.com/economia/brasil-ranking-competitividade-2022/

Muther, R. & Hales, L. (1978). *Systematic Layout Planning*. 4a. edição. Georgia: MIRPB.

Peinado, J. & Graeml, A. R. (2007). *Administração da produção: operações industriais e de serviços*. 1 ed. Curitiba: UnicenP. 750p.

Prates, G. A. (2007) Reflexão sobre o uso da ergonomia aliado à tecnologia: Propulsores do aumento da produtividade e da qualidade de vida no trabalho. RACRE - *Revista de Administração*, Esp. 7(11), jan/dez.

Santos, P. H. A., dos., Souza, A. P., de., Marzano, F. L. C., & Minette, L. J. (2013) Produtividade e Custos de Extração de Madeira de Eucalipto com Clambunk Skidder. *Revista Árvore*, 37(3), 511-188.

Slack, N., Chambers, S., & Johnston, R. (2002). *Administração da produção*. 2. ed. São Paulo: Atlas.

Stevenson, W. J. (2001). *Administração das operações de produção*. Rio de Janeiro: LTC. p. 440-469.

Sule, D. R. (2009). *Manufacturing Facilities: location, planning and design*. 3. Ed. Taylor & Francis Group, LLC.

Taylor, F. W. (2012). *Princípios de administração científica.* 8 ed. São Paulo: Atlas.

Tompkins, J. A., White, J. A., Bozer, Y. A., & Tanchoco, J. M. A. (2010). *Facilities Planning*. 4. ed. New York: John Wiley & Sons.

Vian, E. F. & Junior, A. M. A. (2013). Origens, Evolução e Tendências da Indústria de Máquinas Agrícolas. *Revista de Economia e Sociologia Rural*, 51(4), 719-744.

Villarouco, V. & Andreto, L. F. M. (2008). Avaliando desempenho de espaços de trabalho sob o enfoque da ergonomia do ambiente construído. *Produção*, 18(3), 523-539. https://doi.org/10.1590/S0103-65132008000300009