Proposal for the Implementation of Methods Engineering through the Balancing of the Assembly Line in the Production Process of a Textile Apparel Industry for Women's Denim Garments

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Abstract

Over the years, the motion study method has been proved to be a powerful tool for process standardization in the textile industry, which enables determining the standard time for the performance of a specific task. Moreover, the processing time plays a pivotal role in the management of the production processes when applying the time study technique. Besides, the application of the assembly line balance constitutes a primary goal of manufacturing companies for producing vast quantities in the shortest possible time with satisfactory and efficient results. This research was conducted in a textile company that manufactures denim clothing for women, located in San Juan de Lurigancho District in Lima, Peru. It aims to reduce unproductive time in the production line caused by a poor productive process, excessive movements and long waiting times, by means of applying the method engineering and line balance. In order to obtain the required information for this research, Arena Simulation Software has been used for analyzing the cycle time, productivity and efficiency of small and medium enterprises (SMEs).

Keywords
Motion Study, Time Study, Standard Time, Productivity, Line Balance

1. Introduction
This study focuses on the textile industry and apparel manufacturing sector that represents the third most important economic activity in Peru, which constitutes 6.4% of the manufacturing GDP and generates about 400 000 jobs per year, representing 2.3% nationwide in 2019, as indicated by Sociedad Nacional de Industrias (2021). Therefore, this research will concentrate on the SMEs in the fashion industry, with potential customers located in the commercial emporium of Gamarra, the largest clothing and textile market in Peru. The vast majority of small and medium manufacturing enterprises from the aforesaid commercial emporium ignore the process of efficient production, and prefer to use priori methods, instead. Albujar et al. (2008) claims that they have machinery, technical capacity and management limitations, which lead to a small-scale operation with high unit production costs. Thereby, they present considerable difficulties in complying with quality standards and delivery times.

For this reason, this study aims to show the importance of the Time and Motion Study's theory application, taking into account Line Balance theory. With the aid of these tools, the production process of the textile SMEs can be more efficient, by taking advantage of its resources and optimizing its operations.

Moreover, this research sets out to implement engineering solutions and to increase the production level of SMEs globally. Considering this, the following problem arises: How the application of Engineering Methods and Line Balance techniques improve the inefficient management of the production process so that it complies with the cycle time and can develop an appropriate sequence of operations in a textile company?

1.1 Objectives

As a fundamental objective, the aim of this work is to demonstrate that the application of the engineering method paired with line balancing improves the production process of an apparel manufacturing line in a textile company. In the first place, employee movements within the process will be identified. Afterwards, motion and time study tools will be applied in order to control the travel distance and reduce movements that do not add value. Subsequently, line balancing technique is applied in order to minimize the number of workstations and therefore to comply with the given cycle time. It is necessary to improve the work sequence of each task within every workstation at a constant pace, aiming to balance the workload assigned to each operator within each workstation, hence the assembly line of women's denim pants can be properly completed. For this reason, the application of the chosen methods will be conducted to optimize the production line.

2. Literature Review

The pioneer of motion classification was Gilbreth, who published for the first time the principle of analyzing works by dividing them into basic actions called "Therbligs", which indicates that the subclassification of hand, or hand and eye motion were key concepts in the development of the motion study. (Kanawaty, 1992). According to Barnes (1968), "the motion time system provides also the most scientific, reliable and secure basis for rating operator performance by eliminating the controversies associated with the rating based on the time study".

It should be noted that the first studies about the notion of time study were presented by Frederick Winslow Taylor, who focused on the use of the chronometer. Moreover, Glassey (1966) established the performance rating and developed the procedure of work study, while Merrick (1919) suggested that fatigue and other tolerances should be added to the measurement of working time. Furthermore, Bedaux established rest-recovery periods as part of the work measurement, and then expanded to personal and fatigue leaves. Later, Wiberg (1951) incorporated the performance of the operator to the reduction of the work time in relation to the repetitions.

According to Dragcevic et. al (2002), "in order to establish accurate time norms for the organization of production processes, it is necessary to have a global vision of all aspects, such as the operator's level of skill and the fatigue that manifests itself as a reduction of precision, and, as a consequence, a reduction of the performance's quality in a specific operation Although it is true that productivity depends on the ability of the operators, the direction of the supervisor in charge also has a great influence. To adopt this approach, the study of working time is the duration of each piece to be assembled in the production and activities lines, which is confirmed based on the research conducted by Grzechca (2011). Besides, the delivery of products in the shortest time possible represents a challenge that SMEs usually have to deal with. Thus, Barrientos et al. (2020) mentions that work standardization is the most effective tool as it can reduce time and the number of defects in a manufacturing company. This is demonstrated through the use of the Standard Work Combination Sheet in a studio increased working time by 25%.

Moreover, the research conducted by Aregawi et al. (2017) concluded that identified bottlenecks can be removed or minimized through the reassignment of existent resources to operators and machines in order to maximize resources. Hence, a new model using Arena OptQuest with different possible scenarios and considering resource limitations was developed, which increased the line efficiency to 75, 3%, and resulted in a production of 650 t-shirts with a workforce of 16 people. This computer model can be applied to similar or different multifaceted manufacturing industries that want to analyze and improve production system performance.

About the distribution of workstations, Grimaldo et al (2019) indicates that "based on the description and observation, it was possible to show that the space designation of each workstation without any evaluation of the process flow is inappropriate for the proper development of the production process since it hinders the flow of materials. Furthermore, it was observed that there are delays in the process due to the long transportation time". It is important to point out that Bryton (1954) indicated that in the assembly line balancing problem, the number of workstations is fixed, workstations time are the same for each station and that the working elements move between these stations.

For Akansel et al (2017), the equilibrium of workload is used to distribute the jobs among the resources minimizing the imbalance. In order to get an effective workload balancing, a proper work measurement technique is used so as to obtain the right standard time data.

3. Methods

The research carried out is a case study. Yücel (2011) affirmed that a clear goal of the case study methodology is to gain knowledge to understand how and why events happen. Evidence for case studies can come from six main sources: documents, file records, interviews, direct observations, participants observations and physical machinery.

The research design adjusts to the quasi-experimental design, where, according to Fernandez and Baptista. (2014), "subjects are not assigned randomly nor paired, but are already-formed groups, intact groups; the reason why they arise and the way they are integrated is independent or apart from the experiment." The population of the study comprises all the manufacturing companies in the textile sector. Besides, a non-probability technique was used for data collection; according to Fernandez and Baptista (2014), this sample selection does not rely on probabilities, but on causes related to the characteristics of the research or researcher's purposes.

When analyzing the diagnosis of the company's production process, it is identified that the overlong standard production time, the high rotation of unsystematic movements that employees perform in the assembly area, and the operator and machinery idle time, influence on the company's productivity. What is more, the unsuitable design of the facilities leads to excessive movements when performing scheduled tasks, causing employee downtimes, and therefore, affecting the workstation's efficiency and the increase in the standard time of operation.

In order to carry out a diagnostic analysis about the current situation of the textile company, a tree diagram was developed as shown in Figure 1 and thus identify the causes, consequences, and the main problem in the production of the SMEs under study.

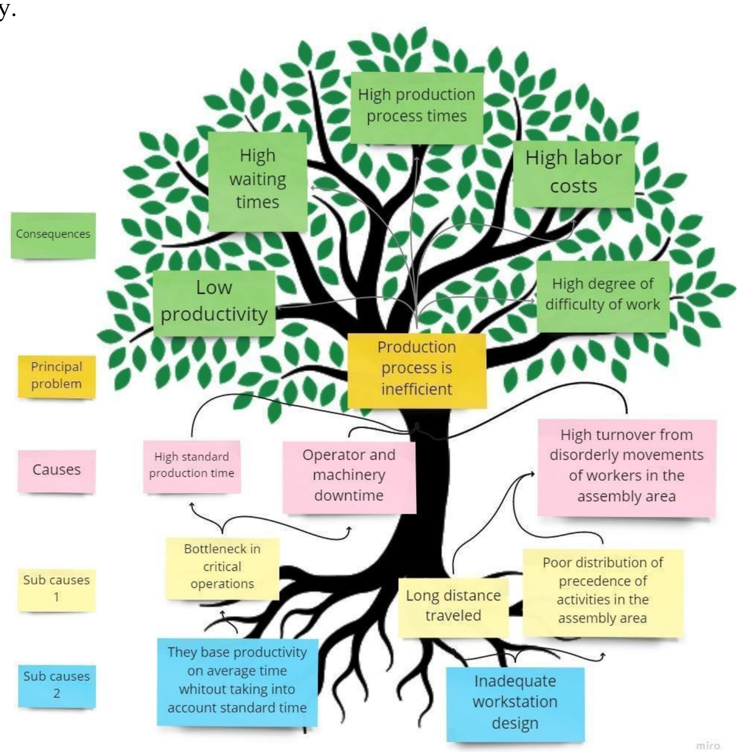

Figure 1. Issue Tree / Logic Tree

It is known that the company carries out its operations based on the gained experience which has led to an increase in the market share; however, the prior method used by the company has reached a point where it is not efficient enough anymore. Hence, it is inferred that the system used in this company does not take into account process problems, since the business is apparently running smoothly. Nevertheless, it actually operates without making the most of its resources capacity since activities that do not add any value to the production process lead to a poor efficiency.

According to the issue tree analysis at the diagnostic stage, it was identified that the main causes are the unsuitable design of workstations, high rotation of employee movements in the manufacturing area, and the overlong standard production time. Therefore, it was found that the main problem is the inefficient management of the production process due to the lack of time standardization in the operation performance, which reflects in low productivity. For this reason, having identified the main causes, solutions for improving the diagnosis can be provided in order to have a significant impact on the production area. These solutions are: Work Study and Assembly Line Balancing techniques. The application of these techniques can lead to a significantly improved sequence of the garment production process in textile companies, and, consequently, to the reduction of unproductive time and unnecessary movements, and the improvement of the work balance.

From this, it is identified that there are variables that participate in the activity such as travel distance, the degree of difficulty, assembly skill, load of the object, among others. These variables can intervene in the cycle time of the set of activities part of the production process. For this reason, when conducting the work study, it is possible to improve the distribution, load and design of the garment manufacturing area in the preoperative stage, which smooths the way for improving the productive method.

4. Data Collection

In the next figure 2, the activities of the production process were analyzed through a relationship diagram, where we can see six (6) absolutely necessary processes, six (6) specially important processes, three (3) important processes, and three (3) undesirable processes. For the diagram analysis, the second floor where the sewing area is located has to be taken into account, as the cutting area has only one operation. It is observed that there are operations which are not close enough and whose location can be modified in order to optimize the production line. Moreover, the excessive number of flow line crossings affects the location of the operations in a negative way; in other words, these locations are not set correctly.

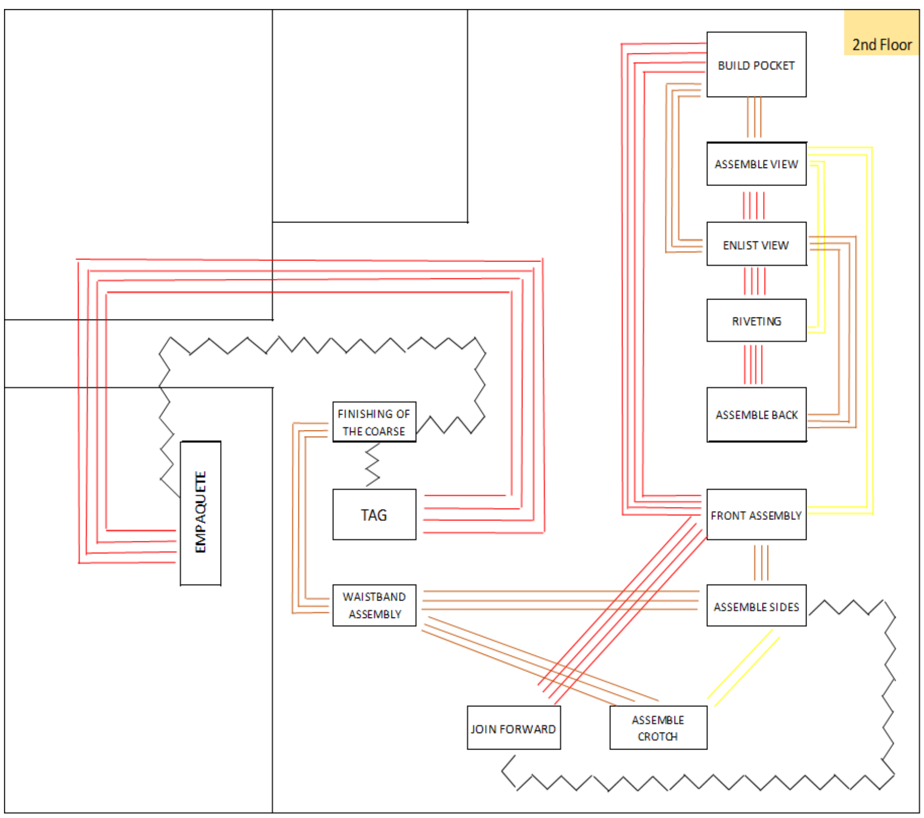

Figure 2. Relationship Diagram

Furthermore, it is important to take into account the travel distances at all stages of the production process. That is why figure 3, where all the levels of the company are shown, analyzes the locations of the activities and the distances involved in the production of women's denim pants.

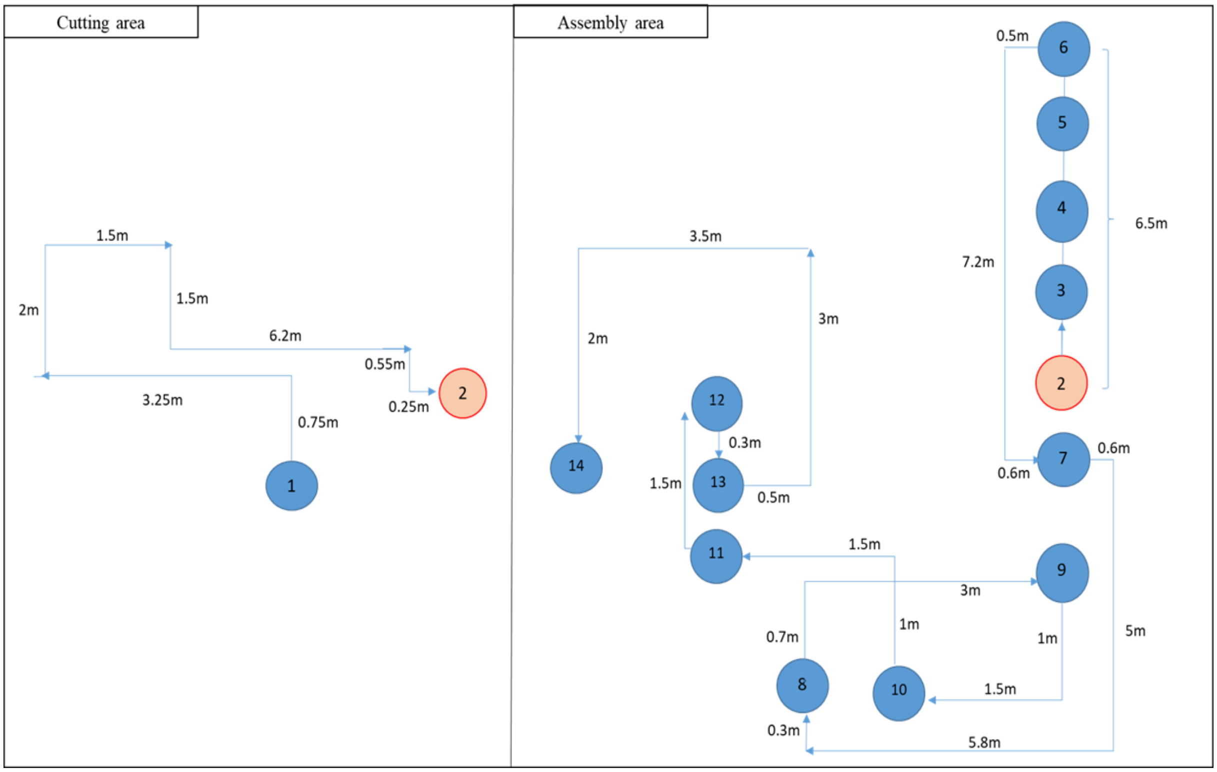

Figure 3. Operations Flow Diagram

With the previous image, it can be seen that the distance necessary for the production process is 62 meters: 16 meters for the cutting area and 46 meters for the assembly area.

In order to carry out a method engineering study, it is fundamental to make a prior approach to the standard time of the SME. According to the authors Freivalds and Niebel (2013), the standard time study is defined as the actual time for performing a specific task, including the respective compensation for fatigue, and personal and unavoidable delays. The time required by a fully qualified and trained operator that works at a standard pace and making an average effort to perform the operation. Moreover, Rehman et al. (2019) demonstrated that the standard time is the time that a qualified and trained operator takes to complete a specific task while working at an efficient yet sustainable pace, using methods, tools, equipment, workplace layout and specific working conditions.

With the information provided by the company, based on the last production of pants, the standard time per task was obtained. This company collects data through the validation technique with the direct observation register of fifty observations where employees were supervised. Besides, the participants that validate the information are the operators and the head of the production area.

Based on the aforementioned information, the time of each operation is expressed in minutes. For each activity or task of the production process, the valuation factor is assigned based on 1 for operators who work with a normal efficiency range. Values less than those indicate that operators are on a learning curve, and those greater than 1, mean that they have an experience of more than 5 years in the textile sector. It is important to notice that the company incorrectly designated the average time of the activity as the standard time, ignoring the overtime and valuation factors, so they did not have an accurate standard time. Thereby, the pertinent calculations were carried out.

For time measuring, in order to establish the average time for each activity or task, employees were supervised while performing their scheduled work. Working time was timed taking into account bonus time given to employees, in order to consider personal time, interruptions, and machine breakdowns or fatigue.

Table 1. Standard Time

Activity	Process operation	Average time (min)	Normal time (min)	Standard time (min)
Cut pieces	1	234,45	234,45	283,69
Assemble back 1 piece	2	1,17	1,17	1,25
Back patching	3	0,42	0,47	0,50
Enlist full view	4	0,67	0,67	0,72
Watch Pocket Assembly	5	0,24	0,24	0,26
Pocket Assembly	6	0,83	1,00	1,06
Assemble front 1 piece	7	0,56	0,78	0,83
Joining assembled parts	8	3,72	4,46	5,00
Sides Assembly	9	2,59	2,59	2,82
Crotch Assembly	10	0,96	0,96	1,01
Waistband assembly	11	7,83	7,83	9,08
Finishing of the coarse	12	1,29	1,29	1,32
Tagging	13	0,75	0,75	0,76
Packaging	14	9,09	8,91	9,36

After getting the standard time per task or activity, the total standard time was divided between the number of observations, which is 50, indicating a standard time of 6,35 minutos per pair of jeans.

5. Results and Discussion

5.1 Numerical Results

In order to define the diary production of the company, it is important to identify the operation with the longest standard time. It is important to mention that the first operation 'cutting' was not taken into account in figure 4, as for the line balancing analysis we will focus on the sewing area.

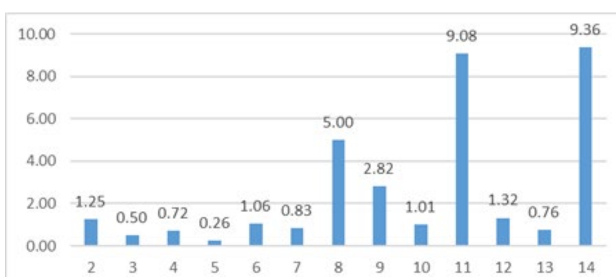

Figure 4. Cycle Time

In the previous graphic, it can be seen that the fourteenth operation determines the production: 9,36 minutes/pants, which is the cycle time. Taking into account that the average work schedule is ten hours per day in two shifts, it can be stated that:

$$Time = 10\ hours/day\ x\ 60\ minutes/hour = 600\ minutes/day$$

$$Production = \frac{600\ minutes/day}{9.36\ minutes/pants} = 64.103\ pants/day$$

From the previous calculation, it is defined that the daily production is 64 pairs of pants, indicating an efficiency of 42,7%. This result is based on the manufacture of 150 clothing pieces per day, which, taking into consideration the number of employees, is the ideal production.

Currently the production system has one cutting process station and ten assembly stations, being a total of 11 stations.

Taking into account the data collected previously, we proceed to calculate the Equilibrium Rate of the sewing line.

$$Equilibrium\ rate = \frac{\sum_{i=1}^{13} Ti}{Ne\ x\ Tc} x\ 100\% = \frac{58.95}{11\ x\ 9.36\ x} x\ 100\% = 57.26\%$$

Where:
Ne: Number of workstations
Tc: Cycle Time
Ti: Man-hour of each workstation

With the result obtained from the rate, the loss of balance then can be calculated
$Loss\ of\ balance = 1 - 57.26\% = 42.74\% > 30\%$

The last results show that the production line requires an improvement of the workstations, since the loss of balance exceeds 30%. For this reason, the sequence of movements in the operations must be modified.

To do this, we determine the minimum number of stations that must be taken into account when improving the equilibrium.

$$No.Min\ St = \frac{\sum_{j=1}^{n} Tj}{Ne\ x\ Tc} x\ 100\% = \frac{33.97}{9.36} = 3.63 \equiv 4\ stations$$

Where:
$No.Min\ St$: Minimum number of workstations
Tc: Cycle Time
Tj: Time for task J

5.2 Graphical Results

Having formerly calculated the number of stations that the production needs, we proceed to indicate the simulation of the process. Simulation is an important tool since because of it the analysis of the current situation and the identification of the steps required to balance an assembly line, are possible. One of the most important objectives of the simulation is to observe the unequal distribution of the assembly line stations and the queues during production. As a result, it was found that there were multiple similar problems in the current production lines, indicating a need for redesigning these lines in order to avoid ‘time wasters and queuing.

Thereby, the author Aregawi et al. (2017) mentions that the analysis of the simulation is used to model the company and it can also be used to quantify the efficiency of the design, the arrangement of works, the handling of materials, the use of resources such as money, machinery, material and man, inventory, quality (like rework, defect, and normal), production cost and processing time.

For the production of selected denim garments (women's pants), the simulation will be developed using the ARENA 16.1 simulation software. All the operational processes will be designed on this program through flowcharts in order to simulate the actual construction of the system model. The direction of the developed model for the complete production procedure is shown in figure 5.

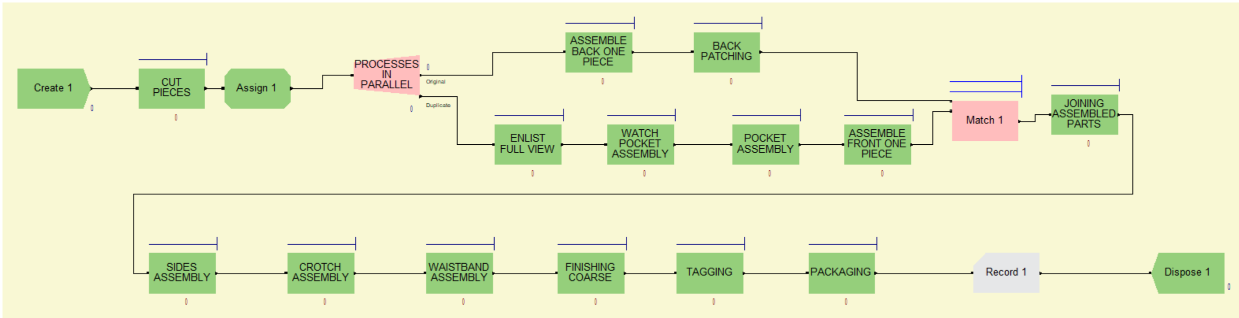

Figure 5. Initial simulation

When running the simulation of the initial scenario, it is verified that the diary production is 64 pairs of pants. In addition, emphasis is placed on the waiting times in critical operations, which are: “packaging” with 112.41 minutes and “blending” with 11.19 minutes. Moreover, it is important to mention that for this simulation 22 operators intervened in the production process.

5.3 Proposed improvements

In order to reduce the loss of balance, it is fundamental to properly establish the number of stations so production can be optimized and more efficient.

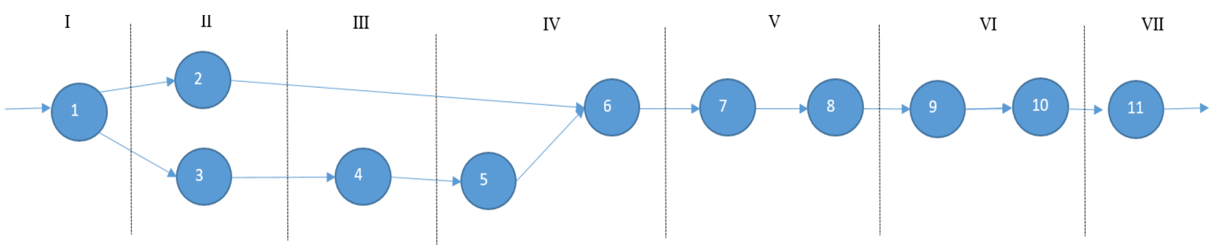

Figure 6. Precedence Diagram of the Optimized Stations

Taking into account that the minimum number of stations is four, it was managed to adjust to a maximum possible of seven stations as shown in Figure 6. With this new data, it is calculated that the new Equilibrium rate of the sewing line.

$$Equilibrium\ rate = \frac{\sum_{i=1}^{13} Ti}{Ne\ x\ Tc} x\ 100\% = \frac{58.95}{7\ x\ 9.36\ x} x\ 100\% \ = \ 89.97\%$$

With the result obtained from the rate, the Loss of Balance is then determined.

$$Loss\ of\ balance = 1 - \ 89.97\% \ = 10.03\%$$

The result is lower than the 30%, meaning that it is an optimal assembly line equilibrium.

In order to improve the workplace design, the material flow has to be improved. Thereby, an “U” shaped design was proposed, as shown in figure 7 where assembly starts in operation 2 and it finishes in operation 11. In this design, we are focusing only on the assembly area, since the cutting area cannot be repositioned. It was detected that watch pocket assembly and front pocket assembly use the same machinery and resources. So, in order to optimize the process, they were merged. As a result, the travel distance and time decreased.

Therefore, the same method was applied with the next four operations, resulting in a total of eleven stations, as figure 8 shows. The assembly line was modified completely, which reduced the distance that the work pieces travel from the cutting area to the packing area, from 62 meters to 39.2 meters.

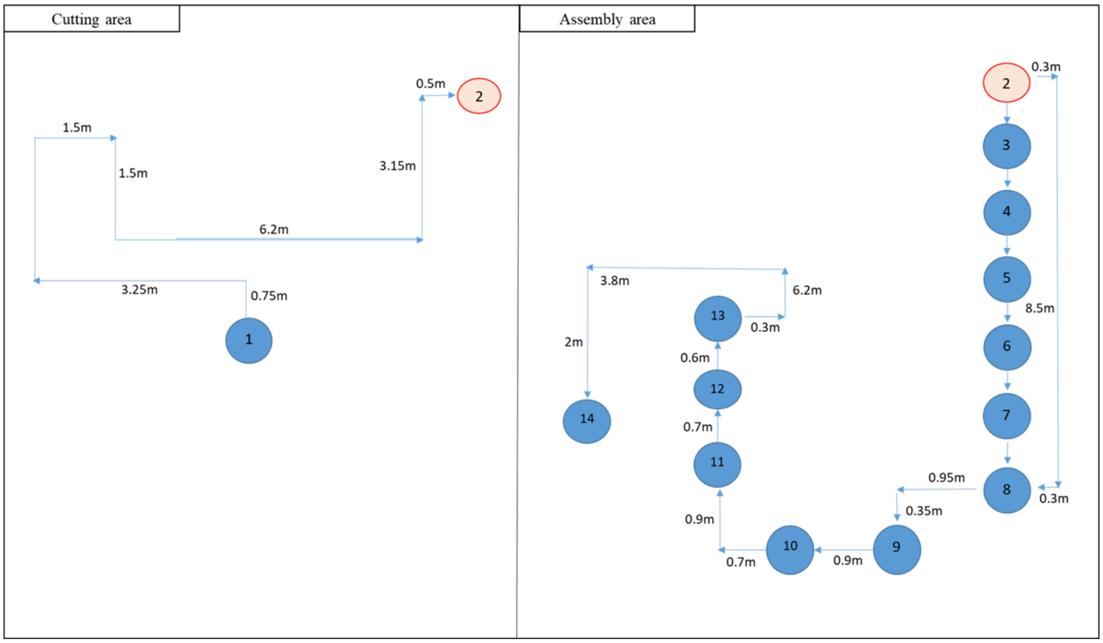

Figure 7. Improved Diagram of Operation Flow

Subsequently, taking into consideration the optimization of the station number, a new simulation is made with the specific changes and the best proposals, resulting in a total of 12 operations for the production process. It is the efficient system of the activities that has led to this reduction and optimization of resources like operators and machinery.

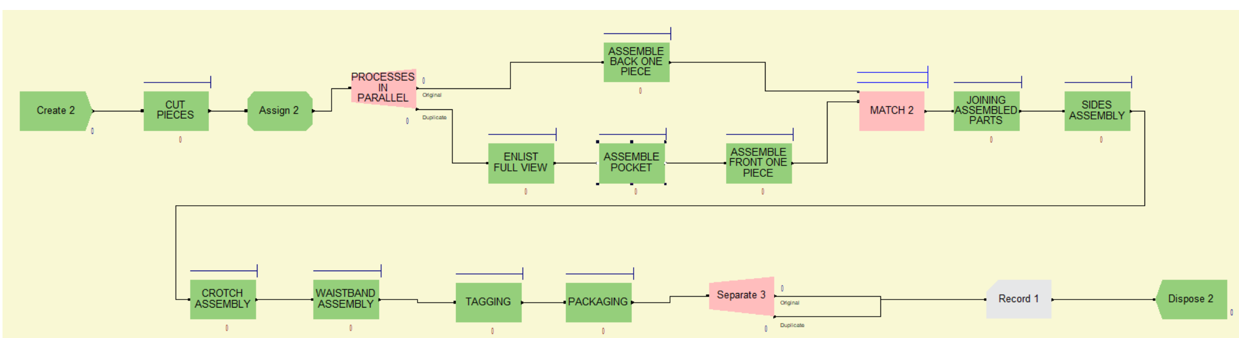

Figure 8. Simulation after Improvement

In the last scenario, it can be seen that the diary production is 86 pairs of pants; besides, the waiting times in critical operations were reduced: "Packaging" operation with 7.5221 minutes and "Blending" operation with 1.265 minutes. Moreover, the number of operators that intervened in the production process was reduced to 17.

5.4 Validation

Similar studies use tools like engineering methods in order to increase the production units during a working day and meet the objectives proposed in its annual planning (Andrade et al, 2019). This case of study also used the assembly line balancing. Quispe-Roncal et al (2020) indicates that in order to improve a process that includes operators and machinery, it is necessary to consider a mixed methodology where both factors are taken into account. Its effectivity can be seen in the reduction of waiting times in the production of the studied company: A packaging operation 93.3% more efficient than the first scenario, as well as the merging operation, which improved significantly 88.7%.

The author Xu et al (2018) demonstrated that the equilibrium rate is calculated by dividing the working time of a workstation with the cycle time; the efficiency of the line balancing was measured dividing the average working time with the maximum working time of all workstations. This is applied on this research, showing an improvement in the rate of the final scenario with 89.97%, and achieving an optimal equilibrium of the stations. Afterwards, by identifying the movements of the manufacturing line using the Operation Flow Diagram, the total traveled distance decreases in 39.2 meters, optimizing 43.2%. Besides, when optimizing the operations, it was found that the number of workers can be reduced from twenty-two to seventeen and the number of workstations can also be reduced from 11 to 7. Finally, the performance of workstations diary productivity was improved in the simulation, producing 86 pairs of pants, and leading to a 57.3% more efficient process.

6. Conclusion

The movements of the workers within the process were identified. Then the time and motion study tools also were applied, leading to the control of the travel distance and to the reduction of waiting times that do not add any value. This was done with the aid of Arena Simulation. Last, while developing the line balancing technique, the number of workstations was reduced; thus, demonstrating a significant increase in production. These improvements will help to demonstrate to SMEs that within a work system it is possible to optimize productivity using the application of work study paired with line balancing.

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Biography

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