Workmanship Balancing of a Production Line in Personal Care Industry

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Abstract

Always changing world scenarios require industries to constantly optimize their processes and resources to remain competitive. In this aspect, one has the importance of the production engineering to act in front of the decision making. The present work was carried out in practice in a hygiene products industry in the south of Brazil, in the company's manufacturing sector. As a case study, and using statistical and mathematical tools linked to production planning and control, it can be concluded that activities can become more balanced among employees with the withdrawal of an employee of the sector, making the efficient production, making it possible to reduce costs and reduce time wasted.

Keywords
Line balancing, Simulation, Time study, Planning and production control.

1. Introduction

With the first Industrial Revolution, initiated in the mid-eighteenth century, production systems began to worry about the need to expand production, optimizing the processes and resources involved, creating a new conception of work.
However, it was not until the beginning of the twentieth century that the Scientific Administration, a concept pioneered by Frederick W. Taylor, which began to identify working methodologies, was able to establish methodologies to improve processes. Taylor (2010), in his work, was concerned with showing that the activities involved in the processes can become more efficient over time, provided there is a prescription of the (standard) execution methodology for each of these activities.
For Barnes (1977), there are several procedures that can be used in problems linked to productivity. One of them is worth mentioning: chronoanalysis, which seeks to stipulate the standard time of each activity through some techniques.
Thus, essentially in the last decades, the balancing of production lines has become a tool that makes it possible to evaluate the system as to its capacity and also to highlight points that can be improved, and it can be used of chronoanalysis as a contribution to the balancing.
In view of the presented context, the objective of this work was to map the current scenario of the cotton manufacturing sector of a personal hygiene industry, regarding the occupation of the resources, besides seeing the changes to be established and suggest possible scenarios of changes, to do the balancing of workforces.
This is because the lines that have a balanced balance show a clear and continuous flow of work, because the employees carry out the activities at the same pace, obtaining a greater degree of a possible application of the labor and equipment. The greatest difficulty in balancing a line, which was denoted in the execution of this work, is in the set of tasks that have the same duration. Generally, activities are performed over large time intervals, with considerable execution times.

Turning to the question of human labor, which is the main focus of this work, Buzacott (2002) analyzed how the differences between workers impact a production system since there are differences in the execution of each activity. Thus, there are ways to analyze the process as a whole and to adapt the activities and the operators in the execution of tasks, improving the performance of the system.
In this work, it will be shown how the reallocation of activities among employees can influence the efficiency of the system.

2. Literature review
2.1 Production line balancing

The assembly line balancing is one of the problems of industrial engineering most approached by the operational research, with works published almost fifty years ago. The study of production line balancing becomes extremely necessary in view of the current competitive landscape. In addition, it is strictly related to continuous improvement, which should be part of the company's culture. Production line balancing is leveling the workload along the value stream to remove bottlenecks and excess capacity (KUMAR, 2013).
According to Rocha (2013), in order to balance a line, it is essential to adapt the demand required to use the maximum number of workstations, seeking to unify the unit time of execution of the product in its successive operations.
Two parameters are peculiar to the great majority of the variants of this problem: (1) the existence of precedence between the assembly tasks and (2) the cycle time of the line. The first causes is that the beginning of execution of certain tasks is conditioned to the end of others. Therefore, these tasks should be allocated on the same workstations as their predecessors, or in later stations, given the direction of the production flow. The other parameter is the timeline operating cycle, which represents the time interval between the output of two consecutive products in a timeline (Askin & Standridge, 1993).
Furthermore, for Silva and Porto (2008), in the study of the balance of the productive flow, the maximum attention should be given to the bottleneck resources, since these determine the productive capacity, mainly because they have the longest processing time, generating a line of products upstream, and idleness in downstream resources.
Decisions about a physical arrangement are important because they generally have a direct impact on production costs. The physical arrangement by process groups, in the same area, all processes or equipment of the same type and function. Materials and products move around looking for the different processes as they become necessary (Peinado and Graem, 2007).

2.2 Time Study

To perform a task in a company, regardless of its size, it becomes important to standardize it. It is called the Standard Method the time it takes to cycle. According to Oliveira (2006), the time study allows the company to know the time used to produce a part, so it can make estimate of product delivery and how much it can produce, that is, its capacity. For the development and completion of the standard times, there are some methods to be used: timing, synthetic times and work sampling. (Martins and Laugeni, 2005).
According to Silva et al. (2007), in order to avoid waste, especially the waste, the synchronization between the production needs and the capacity of the line should be improved, leveling production with demand.

2.3 Simulation

The simulation model is used to simplify the behavior of any system, which is usually much more complex and has infinite uncontrolled variables. According to Miyagi (2004), this model generally uses several parameters on the operation of the system and, once developed and validated, the model can be used to investigate a great variety of questions about the system and any changes in the system can be in order to predict the impact on their performance. In addition, according to Harrel et al. (2002), the simulation can be treated, mainly, as a tool for decision making. In addition, the authors state that the simulation deals with experimental processes, through the alteration of its structure and of how the model responds to these changes in its structure, environment or its boundary conditions.
Thus, the major objective that drives companies to choose to use the simulation is the fact that implementing something new without good planning can generate high costs, causing a loss to the organization. Prado (2009) states that the situation in which the existing system changes without being sure that the change will work can mean a high risk of injury.

3. Methodological procedures

This article aims to balance the occupation of the employees of the manufacturing sector of a hygiene company in Greater Florianopolis, in Brazil, with the intention of defining the ideal quantity of employees to be relocated by activity and machine. In this way, the research consists of an action research, of exploratory objective and of quantitative nature.

Initially, the mapping of processes of the area to be balanced was carried out. The mapping and understanding of the process were of great importance for the development of the systemic vision and served as an input to the simulation part. This was done through interviews and observations.

Then, by identifying the activities and the entities (intermediary products) involved in the system, one can map the whole process through visits to the company and separate by activities. Afterward, the objective was to collect the times by means of timers, in order to do the chrono-analysis of the system. From the measurements, and through the auxiliary tool of the Arena, Input Analyzer, the attribution of the statistical distributions of time for each activity was obtained. With the statistical distributions and the mapping of defined activities, it was possible to simulate the real system in a simulation software. The simulation was adequate with the reality observed in the practice and the system. From the simulation of the actual system of the company, the improvements and possible scenarios for the company were applied. The goal of scenario enhancements is to balance employee activities and test how best to dispose of activities, making it possible to reduce company costs, thereby increasing profitability.

4. Development

4.1 The company

The company in which the project was carried out deals with personal care products, cosmetics and children's line. This has 25 years of existence and distributes its products throughout the national territory. In addition to its own production, the company also manufactures products for third parties. The high production capacity in all production lines also makes the company one of the largest in the country in this segment. In the flexible rod sector, for example, the company is among the 3 largest manufacturers in Latin America.

The quality of its products is a great differential offered by the company. Currently, it produces, on average, 65 different products. In addition, products such as flexible rods go through more than 18 tests until reaching the final consumer. Audit processes are routinely done by companies contracted by outsourced customers, assuring you an average of 95% approval of the inspected items, demonstrating the standardization and organization of the industry's production process.

The process consists in the separation of the cotton fiber and the homogenization of the same, making available in its proper form. This process of raw material treatment is what makes the use of cotton for sectors that use them, such as the sector of stems.

Of all the products manufactured, most of them have something in common: the raw material - cotton. The company has a large manufacturing sector, which is responsible for processing cotton, and it is from the processing of raw cotton that other lines depend. Since some of the employees have already been in this sector for a long time, there was an accommodation regarding the activities, which are done according to demand. Added to this is the fact that there are no defined activities for each employee, that is, everyone does everything a little and, therefore, there is no balance of activities in this production line.

4.2 Analysis of the productive process

In order to carry out the process mapping of the company's production system, interviews were conducted with employees in the sector, as well as meetings with the company's engineer. Also, after understanding the process, all activities were computed using Microsoft Visio software.

In general, the cotton manufacturing process is the basis for the development of the other products in the company. On the other hand, it is the place where activities are less standardized, with only five employees, who work only during one shift and take turns throughout the week, as a way to let everyone be able to work in different roles to manufacturing. Unlike the other sectors, manufacturing is highly automated, and the necessary manpower, that is, the activities of the employees, are basically the transportation of cotton rolls (intermediate products) and raw material, of making the machinery always at work, that is, that at all times there is matter being processed.

In the company, the manufacturing sector contains three main areas: the batter, the line of cards and the cards. The batter is a large machine that turns the raw cotton into cotton rolls, removing its impurities. The card (carding or carding machine) is a machine that performs the process of carding (or carding). This is widely used by the spinning and weaving industries in the treatment of fiber to be handled in yarn manufacturing. In the same way, in the company in question, the cards process the cotton in such a way as to leave its fibers more pliable. Raw cotton arrives through large packs, so-called packs. There are two types of cotton that the company works on: cotton fiber and cotton Pakistan. Depending on the demand and daily goal, the required cotton-type pack is selected. A new package is opened a few times a day, because of the large amount of cotton each one has.

Regardless of the type of cotton, the first step in the processing of raw cotton is to go through the batter. Initially, the fibers of the cotton are very rigid, and the beater serves precisely to leave the fibers more moldable. Therefore, the packs the cotton is placed manually in the batter. This, in turn, processes the cotton automatically and results in a cotton roll, which may be fiber or Pakistan type. In the scraper, the desired type of weight can be selected as required. At the end of this step, there is a person responsible for removing the roller and taking it to one of the intermediate stocks: at the beginning of the card line or at the side of the scout. Rather, the collaborator removes the drum from the drum by placing it in an (automatic) machine that precisely measures the weight of a sample of the drum in order to verify that it is in accordance with the expected quality. At a standard time, the machine releases the roller, which should go to a balance. Then the employee loads the roll of the machine to the scale, noting the weight of the roll, as well as the type of cotton and the lot. Finally, the employee must transport the roll to one of two intermediate stocks. The great majority of the rolls have as next destination the line of cards. However, as there is interest in products that contain a stiffer cotton, there are some rollers that are routed directly to the cards.

The line of cards is composed of six cards sequenced one behind the other and all interconnected continuously. The function of each card is to carry out the carding process in the cotton, that is, the process that acts in the treatment of cotton fibers. Thus, if the cotton roll starts at the initial line card (card 1), it means that, at the end of the line, the cotton fibers will be more refined and with fewer impurities. However, according to the later application of the cotton roll, it is not always of interest to process it with a high degree of refinement. Thus, the roll does not necessarily have to pass through the entire line, but rather it can enter directly through some intermediate line card. Therefore, since there are six cards, which are listed in order of the process sequence, the cards 4, 5 and 6, which are close to the batter, have their own intermediate stock, wherein the rollers remaining therein will be placed directly in some of these cards. For cards 1, 2 and 3, there is an intermediate stock at the beginning of the card line, and therefore the rollers placed therein will enter some of those cards.

Thus, when the destination of the rollers is to the intermediate stock next to the batter, the collaborator directly places the newly weighed roll in that stock because of the proximity of the resources. If the destination of the roll is to the stock at the beginning of the line, then there is a cart, with capacity for three rolls, that serves to transport them. All these functions belong to the same employee, who does not always perform them in a standardized and sequential way since there is not a single plausible orientation.

The card line is virtually automated. The necessary labor is just to put the rollers to rotate in the line. In this way, there are always collaborators close to the two intermediate stocks in which the rolls are left that have just left the batter. These rollers are placed on top of the machine, with an iron (skewer) that will make the cotton roller spin. Below is a roll of cotton being processed by the machine. When this roll is close to running out of the cotton before it is contained, the employee should remove the cotton spit and extend the rest of the roll (as if it were a rug).

Once this is done, the clerk must pick up the roll and make the transition down, continuing the processing of the cotton at the same time as the previous roll finishes, avoiding to leave the machine idle. At the end of the procedure, the employee must replace the roller above the machine, choosing the closest stock. When the machine contains an excess of cotton, that employee also cleans it. Both employees in the vicinity of intermediate stocks have the task of being aware when the rolls that are already in the line are being finalized and which is the card that is demanding new rolls. Also, there is a collaborator who is at the end of the line.

The cotton, which was previously in roll form, leaves the card line in the so-called "cheese", an easier to process cotton with fewer impurities and closer to the quality of the cotton that goes to the final product. Therefore, the function of this employee is to remove the cheese roll from the line of cards - a high-risk activity - to weigh and note the lot and the weight and, finally, to place the cheeses, regardless of which card of the lines the roll of cotton entered, in the same cart located at the end of the line.

The same collaborator, after a demanded quantity of cheeses, should take them to an intermediary stock located next to the cards. However, there is no standard amount for the rolls to be taken, so that the shipping of the cheeses is not standardized.

The "cheeses" serve to be better processed in the cards, which is the last part of the manufacture of the cotton. There are 6 cards, numbered 7 to 12. Cards 7 and 8 process the cotton rolls that have come straight from the batter without

passing through the card line. Cards 9 to 12 receive the "cheeses" to process. There are four "cheeses" per card, which are searched manually in the intermediate stock.
The beads 7 and 8 are ball cotton, while the beads 9 to 12 form cotton wicks. All brass/packages resulting from the card industry are also taken through a cart, to an intermediate stock out of manufacture, serving as material for the products, thus leaving for different sectors of the company.
As the interest of this article is to balance the workmanship of the manufacturing sector, since there is no way to change the technical performance of the machinery, then one can divide the activities according to the manufacturing sector and the category:
As mentioned earlier, much of the human labor activities are to make machines always in process. Therefore, one can separate the activities in:

- Operational - standard activities that are part of the manual process;
- Process - activity performed by the machine, in a standard time;
- Transportation - activity in order to move intermediate products, either between sectors or intermediate stocks.

The activities related to the processes, except for the time the machine measures the weight, since this depends on how the employee organizes the roll in the machine, removes the excesses of cotton and, thus, the measurement time is varied, don´t having a standard execution time. Thus, one can know the exact moment when the machine will be demanding a new roll or cheese.
Also, in the line of cards, all the cotton rolls are consumed equally, that is, the time is the same for each card in the line. On the other hand, in the cards 9 to 12, which consume the cheeses, four cheeses are demanded at one time to produce the wicks. Each cheese has an average of 10kg, and yet each bag of wick formed contains 10kg. Therefore, the time in which the cheese is processed is the same time for a roll of wicks to be formed. The same happens for the cards 7 and 8, where the consumption time of the rollers is the same time for the formation of a cotton ball bag, however, in the case of the rollers, between a roll of cotton and a sack of wicks comes out by turn.
Thus, through observation and timing, the standard time of the processes involving the machine resources was computed, that is, times that will not change unless the power of the machines is increased. Added to this is the fact that this work focuses on human resources, but standard times were essential to complete the efficiency of the current system.
Once this was done, it was considered necessary to perform a time study of the observed manual activities, in order to obtain data from which they will demonstrate primordial characteristics to carry out the balancing. Therefore, a spreadsheet, through Excel software, was created to record the activities and their respective times collected. In addition, it contains statistical aspects that enable chronoanalysis.

4.3 Statistical model of activity analysis

To balance a production line, you have to manipulate the times of each activity. For the analysis of the times, according to the process mapping, a statistical analysis was performed in order to know how much data for each sample would be necessary to reach a confidence of the data, besides being able to conclude with clarity what activities require a change.
For this, a Student-T distribution was assigned to the time data. This distribution is symmetrical, bell-shaped, and similar to the standard normal curve, but with wider tails. Therefore, a T-Student simulation can generate more extreme values than a normal curve simulation, typical of sampling. Thus, a confidence level of 90 to 95% of the data was considered, depending on each activity counted.

4.4 Time distribution of activities

By putting in the Input Analyzer, an auxiliary tool that comes with the ARENA software, the recipe of the time distribution for each activity was determined. With the confidence level adopted, this formula allows to demonstrate how each activity behaves over time, that is, how its execution time varies during a shift. Then, with the random replications that occur over the days, the time distribution of the various activities fits, with a confidence level of 90 to 95%, the simplified reality of the system, being able to extract conclusions more precise than adopting distributions only uniforms or patterns.

4.5 Simulation of the real system

Using the information mentioned above, a layout was created in the Arena software to simulate the system, based on the execution time of each activity through the distribution of the time found. The simulation integrated all areas of the system (manufacturing sector).
The system was run considering one shift (8 hours) per day, with 50 random replications. The entities leaving the system are: the cotton ball, which comes from the cards 7 and 8 and the cotton wick, leaving the cards 9 to 12.
In addition, through the report that is made available by Arena, it is of main interest the analysis of 3 aspects: time of the entity in the system, the number of entities produced and, essentially, the occupation of the resources.
According to the daily production goal of the company, it was sought to leave the results as close as possible to the actual production. So we took this as the current scenario. From the results of this scenario, one can suggest changes in order to equate the occupation of the employees, besides making the production more stable.
From the real simulation of the system, the results were obtained regarding the number of entities produced and the occupation of the resources involved in the system, in addition to the time that an entity is, in average, in the system.
With the result obtained, and meeting the purpose of this study, the following system resources could be reallocated or improved:

- Operator B: Beater operator;
- OperatorCards: (two) Operators of the Cards;
- OperatorLC1: an operator of the beginning of the card line;
- OperatorLC2: end of line operator;
- Cart 1: trolley that transports the picker rolls to the beginning of the line;
- Cart 2: Cart that transports the cheeses from the card line to the cards.

The number of entities produced in the simulation compared to the reality of the company, which is based on the weight of cotton produced, is quite consistent. From the results of the simulation, turning essentially to the focus of this work, considering the occupation of the resources, mainly of the operators, it is noticed that there is more idleness on the part of the line operators, while the operators of the cards are very busy, surpassing the maximum occupancy established by the company, which is 77%. Therefore, it is perceived that there is an imbalance of labor. From then on, new scenarios with improvements were created with the aim of distributing the occupations of the system and balancing the workforce.
There is a consistent flow of processes. However, there is a considerable amount of time spent by the employees. If each part of the sector (beater, line of cards and cards) were connected in a coherent way, then the transport times would be shorter.
Therefore, thinking primarily about the occupation question, the essential aim with the new scenarios is to equip them in the best possible way. Of the operators of the Line of Cards, it is noticed that the operator of the end of the line (OperatorLC2) is the least busy. Thus, the two scenarios, besides the current one, are:

- Scenario with improvements with the OperatorLC2;
- Scenario with improvements without the OperatorLC2.

4.5.1 Scenario with improvements with the OperatorLC2

In this case, the system would continue with the five employees. The batter operator would transport the rolls to the beginning of the line of cards (3 at a time). In addition, I would put the iron skewer in the new roll being produced by the cart while the roll that just came out of it is in the machine that measures the weight. OperatorLC1 would do, in addition to its current scenario activities, the standard supply of cotton that came from the packs in the batter every 15 minutes for 2 minutes. The OperatorLC2, in turn, would assist in the card industry in the transportation of cheeses and wicks, besides being responsible for the end of the line of cards. The operators of the cards would continue with their activities, with the exception of the latter that would be done by the OperatorLC2.
Then the system would behave in a more homogeneous way. Cards operators are no longer overloaded and have a better distribution of activities, unlike the current model.

4.5.2 Scenario with improvements without the OperatorLC2

In this scenario, developer LC2 would be reallocated to another sector of the company and the manufacturing system would work with 4 collaborators. The operator of the batter, in addition to its activities already mentioned, would perform the functions of LC2, referring to the operation of this function. The transports involved in the activities, from the cheese to the cards, from the wicks and balls to the cart and from the rollers of the beater to the line of cards would be carried out by the operator LC1.

In this way, the occupations of the employees would become more balanced compared to the real system, reducing the differences of the idleness of the operators. This is because one of the company's major problems today is that some employees do not want to take their time because other activities require more time to execute. Therefore, occupations would be much closer to today's system.

In terms of balancing, this model is the most ideal, since all employees have an occupation above 50% of the time, besides the activities, as well as their dangerousness, to be better distributed. Added to this is the fact that the company can relocate the laid-off employee of the industry to another sector, reducing its costs and thus maximizing its profits. The production of entities, on the other hand, remains stable and at the same pace as the current system.

By observing the time of the two intermediate products in the system, it is noticed that in all the improved scenarios, there was a considerable reduction of the time of the balls in the system. This shows that the current system can be much more used than it is today, since it can reduce the productive lead time, maintain production or even increase it, and even distribute the activities in a more homogeneous way.

In summary, after all, data computed and studied, we have the percentage of time spent for each function of the sector compared to the total time of activities spent by all employees in the 3 different systems. For an ideal system in terms of balancing the workforce of 4 employees, each employee should spend 25% of the total time. For 5 employees, 20%, and so on. The following table shows the completed data.

Table 1: % of the time spent by each employee

Operator	System		
	Current	With Operator LC2	Without Operator LC2
Batter	27%	23%	33%
LC1	16%	18%	27%
LC2	13%	19%	-
Cards	44%	40%	40%

The following graphs illustrate the total occupation of each employee in relation to their own occupations, for the three different scenarios:

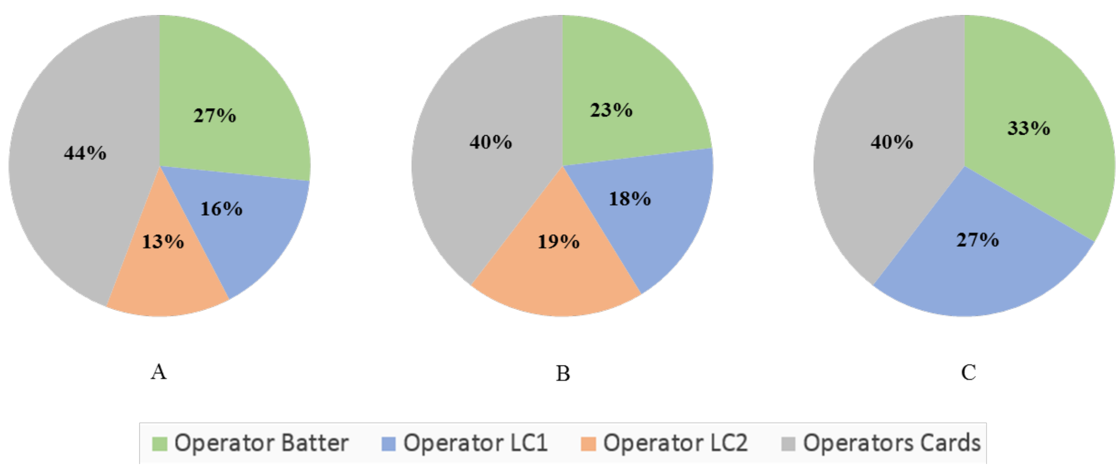

Figure 2: percentage of the time spent by each employee in the current Scenario (A), Scenario with the OperatorLC2 (B) and Scenario without the OperatorLC2 (C)

Thus, following the main objective of this work, the best scenario that equates the occupations of the operators is the scenario with improvements and without the OperatorLC2, through four collaborators without so many differences between them.

5. Conclusions

After following the 4 steps of this work, it is noted that there are many aspects to be improved in the system of the current scenario. The intermediate products take about half a turn until they leave the manufacturing sector. From the established scenarios, it was concluded that the most plausible result regarding the equalization of occupations is with the withdrawal of one of the collaborators. In this case, OperatorLC2 would leave the industry and could be allocated to some other part of the company.

Therefore, the activities, as mentioned in the previous subtopics, would be divided among the four operators, in addition to following a pattern (flow) between the parts of the sector.

In addition, activities in this scenario would be less cluttered because of diminishing resources. Another good option, as demonstrated, would be to change the layout of the productive sector. This would certainly require further study as well as the feasibility of such an investment. Also, the transport times, with the change of layout, would change, and therefore, there should be a new study of the times of these activities to obtain concrete results from the simulation.

Therefore, the changes are plausible and can be executed without harming the current scenario. With this, the LC2 Operator could be allocated to some other location of the company, giving space for optimization, expansion and improvement to the company.

Therefore, the production system adopted would have four employees, in order to allow expansion to the sector and, therefore, to the company. The work allowed to work with several areas of industrial engineering, from process mapping, to chronoanalysis and simulation, being an integrated project with impressive results, as demonstrated in every development.

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