Optimization of the Bicycle Assembly Process by Applying Tools Lean Manufacturing: A Case Study

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Abstract

The investigation was carried out in the workshop area of the company GIANT IBARRA, whose main problem is the delay in the delivery of finished bicycles causing a breach of the demand requested by the commercial area. This reason influences the proposal of an improvement within the production process, which allows a decrease in productive time, guarantees efficiency, and reduces the use of resources that do not add value to the process through the application of tools of the Lean Manufacturing methodology. The development of the proposal required the design and description of operational tools such as 5'S, Kanban, and Manufacturing Cell; for the latter, the new working method that will increase efficiency was determined. Through the Value Chain Map (VSM) tool, it was possible to obtain the results of improvement based on certain indicators, where a decrease in lead time of 27.55 minutes is observed; on the other hand, the production capacity is increased to 27 bicycles generating an efficiency increase of 8.05%.

Keywords
Lean Manufacturing, Lead Time, Takt Time, 5'S, Manufacturing Cell, The 7 Wastes of Lean Production.

1. Introduction
Lean Manufacturing begins with James Watt, who invented the double-acting steam engine in 1776, opening the Industrial Revolution. Later, Frederick Taylor changed the focus of manufacturing in the twentieth century and proposed the division of areas to concentrate on more specific activities which became the standardization of work (Socconini, 2019). For his part, Henry Ford finished manufacturing his first car called the Model T in 1896, of which 15 million units were manufactured; in 1913 Ford created its assembly line and thus revolutionized manufacturing. Sakichi Toyoda who is part of the creation of Lean Manufacturing, learned as a child the trade of carpenter that he would later apply in a great invention, which consisted of a device that made the loom stop is a thread broke, warning with a visual signal to the operator that the machine needs attention, the invention was called Jidhoka in 1890.

1.1 Objective
Optimize production, through Lean Manufacturing tools, which allows for improving the level of service provided

2. Literature Review
(Lorente, 2018), (Buer, Strandhagen, & Chan, 2018), (Maria Pia Ciano, 2021) (F.T.SChan, 2001), (Economics, 2008) (Aydin Torkabadi, 2018), (Leong, et al., 2019), and, (John, Sampayo, & Peças, 2021) companies continuously strive to increase the productivity and production of their operations. Lean has been created and defined as Toyota's waste disposal process along with supporting a system to reduce or eliminate waste and non-value-added activities from various processes. (Abualfaraa, Salonitis, Al-Ashaab, & Ala'raj, 2020), (Kurilova-Palisaitiene, Sundin, & Poksinska, 2018) (Ballé, Chartier, Coignet, & Olivencia, 2019), they propose that the value stream are all the steps, both value-added and non-value added required to bring a product or service of the raw material to the customer. (Xiao-Yong

Zhu, 2020), (Marcin Ziółkowski, 2020) discussed the application of lean production methods to a traditional manufacturing organization.

3. Methods, Results, and Discussion

Through an analysis of the current situation of the company, it was determined that there are causes that affect the adequate use of the working day, where the time dedicated to production is being limited and the demand requested by management is not met.

3.1 Numerical Results

Assembly process times

Table 1 presents the results of the process times for each type of activity; this time is the one used for the production of a bicycle considering the times that add and do not add value.

Table 1. Process Time Results

Activity	Quantity	Time (min)	Distance
Operation	39	143,64	8,4
Transport	2	3,25	4,5
Inspection	2	5,02	2,7
Hold on	3	5,51	0
Storage	1	1,16	2,2
Total	47	158,58	17.8 m

Workflow calculation

In this section, the calculations of the Lean Manufacturing times were made, where it was obtained: lead time, takt time, efficiency, and level of compliance; to establish the current situation of the assembly process of the company GIANT IBARRA.

Lead Time Sourcing: It is the time in which the forecasts of the orders that will possibly occur in the future are made.

$$Lead\ Time = LT\ supply\ +\ LT\ production\ +\ LT\ transportation.$$
$$Lead\ Time = 39.03 + 116.3 + 3.25$$
$$Lead\ Time = 158.58 \text{ min.}$$

After the analysis carried out, it was obtained that the Lead Time for the assembly of bicycles is 158.58, based on its three factors: supply, manufacture, and transport. This result is equivalent to the total production of a bicycle so to produce the 20 demanded per month by management it is necessary to 3171.6 minutes.

Calculation of Takt Time

In this case, we perform an average of working hours since the company has a variation in its schedules. It is known that there are 9 working hours where not all are destined to the assembly process, but it is divided as follows:

- *Availability time: 7 h. = 540 min.*
- *Monthly working hours: 24 days = 216 h.*
- *Lunchtime: 1h. 30 min.= 90 min.*
- *Break 1: 30 min.*
- *Break 2: 30 min.*
- *Time to Clean: 90 min.*
- *Maintenance: 120 min.*

$$Real\ time = Availability\ time - Lunchtime - Break1 - Break2 - C - M$$
$$Real\ time = 540 - 90 - 30 - 30 - 90 - 120$$
$$Real\ time = 180\ min.$$

Now calculate the demand from management:

$$Daily\ Demand = \frac{Management\ Demand}{Monthly\ working\ days}$$
$$Daily\ Demand = \frac{20}{24}$$
$$Daily\ Demand = 0.83\ bicycles/day$$

To finish we get the takt time using real-time and daily demand.

$$Takt\ Time = \frac{Real\ time}{Daily\ Demand}$$
$$Tak\ Time = \frac{180}{0.83}$$
$$Tak\ Time = 149.4\ min./bicycle$$

After performing, the corresponding calculations, it`s can be defined that it takes a "takt time" of 149.4 minutes to obtain a total of 0.83 bicycles per day, so not getting this amount would limit the possibility of meeting the amount necessary to meet the demand.

Efficiency Calculation

Table 2 presents the times that add and do not add value to the process according to the overall process time.

Table 2. AV and NAV time results

N°	Process	Total time	Time Adds Value	Time Doesn't Add Value
1	Workshop sourcing	0:42:28	0	0
2	Armed with hoops	0:23:01	0:22:05	0:00:56
3	Tire assembly	0:34:39	0:33:41	0:00:58
4	Fitting	0:36:43	0:26:44	0:09:59
5	Assembly of bicycles	0:22:47	0:16:23	0:06:24
TOTAL		2:39:38	1:38:53	0:18:17

With the data obtained, the efficiency calculations are carried out using the following equation:

$$Efficiency = \frac{Time\ value\ added}{Time\ value\ added + Time\ non\ value\ added} x\ 100$$
$$Efficiency = \frac{98.53}{98.53 + 18.17} x\ 100$$
$$Efficincy = 84.43\%$$

The company has an efficiency of 84.43%; where we have a waste of 15.57%; assuming that there are activities that do not generate value for the process.

Calculation of the Compliance Level

Table 3 presents the data on the level of compliance for the first half of 2021 based on the requested work orders.

Table 3. Level of compliance with work orders

Level of compliance					
Month	Received	Delivery	Backwardness	Indicator	Compliance rate (%)
January	25	25	0	0,00	100,00
February	23	19	4	17,39	82,61

March	20	20	0	0,00	100,00
April	22	17	5	22,73	77,27
May	25	21	4	16,00	84,00
June	21	18	3	14,29	85,71
Total	136	120	16	11,76	88,24

$$\%Delivered\ on\ time = \frac{Quantity\ of\ orderes\ delivered\ on\ time}{Quantity\ of\ orderes\ receibed} * 100$$

$$\%Delivered\ on\ time = \frac{120}{136} * 100$$

$$\%Delivered\ on\ time = 88.24\%$$

It was found that there is 88.24% of deliveries on time, this data will serve to define the factors that are causing changes during the process.

Production Calculations

Perform the calculation of the production to obtain an indicator that allows us to detect and control the performance with which the current situation of GIANT IBARRA is determined.

Technical-Organizational Requirements (ETO)

These technical-organizational requirements are responsible for measuring the real relationship of the company with the environment, in addition to the response it gives to it; all this in conjunction with the conditions it has to do so. (Orozco Crespo, 2017)

Accuracy

It is the probability of operation of the process during a period without interruptions or problems in the volume, assortment, term, quality, and costs. (Morales Carmouze, Gallardo Capote, Sáenz Coopat, & García Martínez, 2014)

$$A = \left(\frac{Quantity\ of\ orders\ on\ time}{Total\ orderes}\right) * \left(1 - \frac{Quantity\ of\ orderes\ whith\ errors}{Total\ orderes}\right)$$

$$A = \left(\frac{120}{136}\right) * \left(1 - \frac{16}{136}\right)$$

$$A = 78.0\%$$

Through the calculations made it was found that it has an accuracy of 0,78 % based on its orders or orders fulfilled.

Stability

Stability refers to the ability of a system to compensate for or eliminate disturbances that occur in its operation, this requires having an organization that allows it to prevent and solve the problems that appear at the moment without there being a superior entity that acts on it. (Orozco Crespo, 2017). It has the production of the first half of the year 2021, which is the strongest in terms of demand and sales, so it requires a higher production than the year (Table 4).

Table 4. Production of the first half of the year 2021

Month	Production
January	25
February	19
March	20
April	17
May	21
June	18
Stocking	20
Deviation	2,83

$$S = 1 - \frac{s}{\bar{X}}$$
$$S = 1 - \frac{2{,}83}{20}$$
$$S = 86{,}0\ \%$$

Service level
It is an indicator of reliability for the customer, which is determined by quantity, quality, cost, or opportunity. (Mecalux Esmena, 2021)

$$SL = 1 - \frac{Nf}{No}$$
$$SL = 1 - \frac{16}{120}$$
$$SL = 0{,}87$$

As a result, a service level of 87% is obtained, which will be a key indicator to compare based on the second half of 2021.

Production Capacity
We proceed to calculate the production capacity where it is necessary to obtain the productivity it has for it to increase and benefit the company, in this way define how much more can be used if the correct management of all its resources is carried out.

Production times
The production time is calculated per unit where the time that adds and does not add value is used

$$Production\ time\ per\ unit = Time\ value\ added + Time\ non\ value\ added$$
$$Production\ time\ per\ unit = 98.53 + 18.17$$
$$Production\ time\ per\ unit = 116.7\ min.$$

It took 116.7 minutes to assemble a bicycle, so a month needs 2334 minutes to make 20 bicycles. Considering that the company does not have an internal organization and that the jobs are rotating, it has been seen that the supply time has been affected due to inconsistencies, after an analysis of the sample taken as a basis for the investigation, it was reached that the time to get the necessary materials is 39.03 minutes per bicycle, giving a total of 780.6 for the monthly amount. Demonstrating that the total production time is given by:

$$Total\ production\ time = Supply\ time + manufacturing\ time$$
$$Total\ production\ time = 780.6 + 2334$$
$$Total\ production\ time = 3114.6\ min.$$

That is to say, that to produce the 20 bicycles it takes 21.63 days of the month, which can be read by applying the improvements within the process and avoiding downtime or waits that cut the workflow.

Productivity
You need to get the productivity of the company by applying produced units and total working time. Table 5 presents the data for the calculation of productivity.

Table 5. Data for calculating productivity

Data for productive capacity	
Working days per month	24
Working hours per day	9
Working hours per month	216
N° of bicycles	20

Cycle time (min/bikes)	158,58
Total production time (min)	3114,6
Total production time (h)	51,91
N° workers	2

With the data presented in the table, we proceed to calculate productivity based on the units produced and the production time per month. We apply equation 4 for the calculation of productivity where we have the following:

$$Productivity = \frac{20\ bicicles}{51.91\ hours}$$
$$Productivity = 0.38\ bicicles/hour$$

Then we obtain the productivity of labor by the following equation:

$$Man\ hour\ productivity = \frac{Total\ units\ produced}{Total\ time * workers\ employed}$$
$$Productivity = \frac{20\ bicycles}{51.91\ hours * 2\ workers}$$
$$Productivity = 0.19 \frac{bicycles}{hours * worker}$$

With the results obtained, we can say that labor productivity is 0.19 bicycles/hours, workers thus demonstrating that there is low performance in their performance, this is because there is a poor distribution of tasks as has been reflected in the visits to the company when observing how mechanics leave their job to perform other tasks. In addition, we see that there is productivity of 0.38 bicycles/hours per month which directly affects the monthly production preventing the fulfillment of all production orders.

Real production capacity

After obtaining productivity, the real production capacity of the company is calculated.

$$Real\ production\ capacity = \frac{Units}{Available\ real\ time}$$
$$Real\ production\ capacity = 0.38 \frac{bicycles}{hours} * 2.49 \frac{hours}{day} * 24 \frac{day}{month}$$
$$Real\ production\ capacity = 22.71 \frac{bicycles}{month}$$

The company has a current production capacity of 23 bicycles per month, taking into account a time available for the assembly process of 2.49 hours for 24 days of the month, if the mechanic is dedicated to producing during the 9 working hours taking into account only the breaks, lunch and cleaning time, the production capacity would be higher than what was demanded but it must be taken into account that according to the needs of the company and the services provided only generate these values.

Installed production capacity

It is obtained using the number of units and the time available, knowing that you have 5.5 hours to produce, we find the following:

$$Production\ installed\ capacity = \frac{Number\ units}{Available\ time}$$
$$Production\ installed\ capacity = 0.38 \frac{bicycles}{hour} * 5.5 \frac{hour}{day} * 24 \frac{days}{month}$$
$$Production\ installed\ capacity = 50.16 \frac{bicycles}{month}$$

Based on the calculations made, it was found that the installed production capacity for the company is 50 bicycles per month only if of the three mechanics 2 were dedicated only to the assembly of bicycles and one to maintenance with the support of the workshop assistant (Figure 1).

3.2 Graphical Results

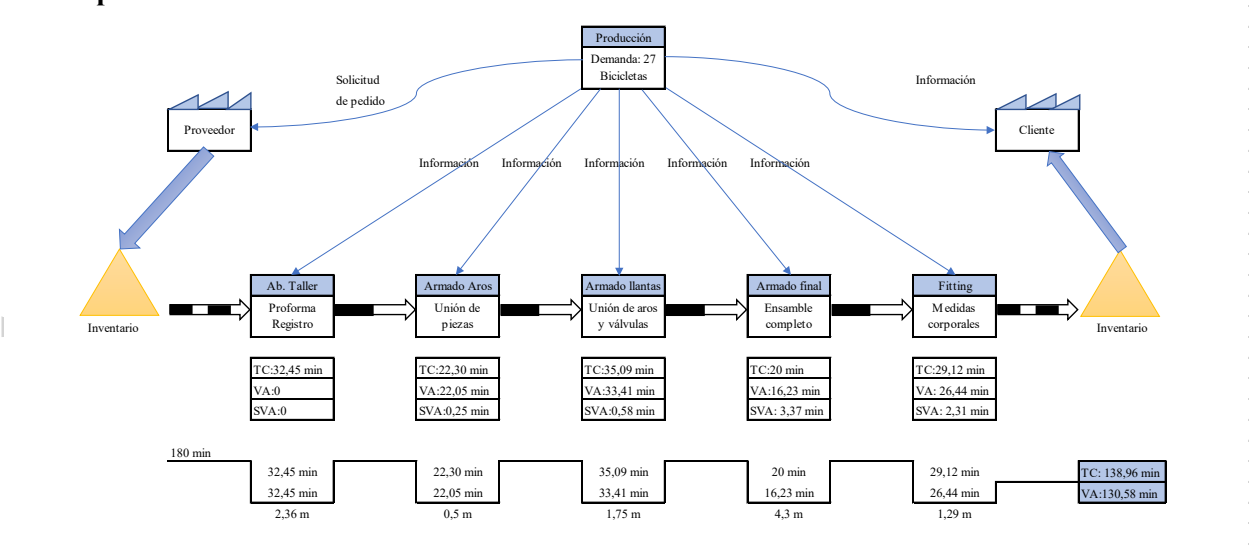

Figure 1. VSM Prophets

3.3 Proposed Improvements

Based on the results obtained, Table 6 defines certain indicators that will help generate the proposal based on the improvements that must be made.

Table 6. Current situation indicators

Indicators for the Proposal		
Indicator	Results	Proposal
Time that does not add value	18.17 min	Reduce or eliminate
Distance traveled	17.8 m	Reduce
Lead Time	158.58 min	Reduce
Efficiency	88,54%	Increase
Level of compliance	88,24%	Increase
Production capacity	2.28 bicycles/day	Increase
5's	46%	Increase compliance with the Checklist.

With the analysis carried out it was known that the problem that was generated were the delays in the assembly process, considering that the subprocesses of assembling rings and tires had a bottleneck in the passage of their operations, applying lean Manufacturing tools generated tasks and activities that are potential to help this problem.

1. 5S: Applying the principles of order and cleanliness, a methodology was developed that contributes in certain measures to the selection and location of articles that are not of necessary use for the process, in addition to

implementing a cleaning and disinfection system through a planning that records the work of each designated worker. All this in order to standardize certain activities and track the application of Checklist of the 5S.

2. KANBAN: The design of Kanban cards seeks to reduce delays or permanently eliminate the existing bottleneck. Another contribution is to plan how much should be produced and how much is needed for each thread.

3. Manufacturing Cell: This method was necessary to properly distribute the work areas, being thus that the main warehouse and the workshop were unified due to the space and the physical and environmental conditions.

4. Working method: Developing a new method by locating the activities and production times can be achieved to have better results and an increase in productivity.

After performing the analysis of each key indicator for the performance of the company and applying the aforementioned tools, the improvements are obtained and observes that there is a decrease in time that does not add value, which influences productivity to rise as well as productive capacity, thus fulfilling the main objective that is the improvement in the performance of the process.

4. Conclusion

1. Based on the documentary research of the company, fieldwork, and application of the VSM tool in it, it has been found that the workshop has shortcomings that start from its planning, where the existence of over processes and waits within the assembly of rings was found which directly influences the general assembly time.
2. The Kaizen Events allowed to determine the strengths and opportunities that the company has, so by establishing strategies that improve its performance, it was possible to increase the efficiency of the company from 84.43% to 92.48%.
3. The 5s were of utmost importance to generate a habit of order and cleanliness which influenced that there is a better organization and therefore there is a decrease in time that does not add value in a total of 3.94 minutes thus seeing an increase in the evaluation of the 5s starting from the current situation with 46% to the data obtained through the proposal of 84%.
4. By applying the design of the new working method and the manufacturing cells, it is possible to reduce the cycle time from 158.58 minutes to 131.03 minutes, in the same way the distance or travel during the flow of the process was shortened since the warehouse 1 and the workshop were unified, thus being a route of 10.14 meters with respect to the current situation which denoted a total of 17.8 meters; this through the support of the 5s to locate the materials and resources that evidenced an improvement in their productive capacity to 27 bicycles per month increasing their productivity to 0.45 bicycles/hours.
5. The establishment of a working method through the pre-assemblies contributed to the increase of the fulfillment of the orders eliminating the existing waste being the most important the delays in the processes, that is how, the bottleneck originated in the subprocess of assembly of rings was eliminated giving way to a continuous productive flow.

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