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Standard Predetermined Time on Line 4 of the Sub Assembly Area in an Aerospace Company

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Abstract: This study aimed to determine the workload of operators on a production line in an aerospace-sector company, with the goal of increasing operational efficiency by at least 17%. The methodology involved analyzing the process under study, determining the cycle time, calculating the takt time, conducting workload balancing among operators, and evaluating overall efficiency. The main results demonstrated a reduction in staffing from 14 to 11 operators, yielding a 17% decrease in labor costs and a 17.48% improvement in efficiency. It is concluded that the post-balancing scenario produced a positive outcome, indicating a satisfactory enhancement in the efficiency of the subassembly line.

Keywords: Aerospace, Cycle time, Efficiency, Takt time, workload

I. Introduction

The global aerospace industry originated and experienced its greatest expansion after World War II. According to [1], the industry is the result of the convergence of the aeronautical and space sectors. The former focuses on the first layer of the atmosphere, where most aircraft operations take place, while the latter extends beyond the atmosphere, with satellite-based communications as its principal area of activity.

In Mexico, 80% of aerospace companies specialize in manufacturing, 10% in engineering and design, and the remaining 10% in maintenance, repair, and overhaul services.The Mexican aerospace sector is the second largest in Latin America, contributing more than 3.5% of the country's economic activity in 2019 and reporting exports valued at approximately 10 billion USD [2].

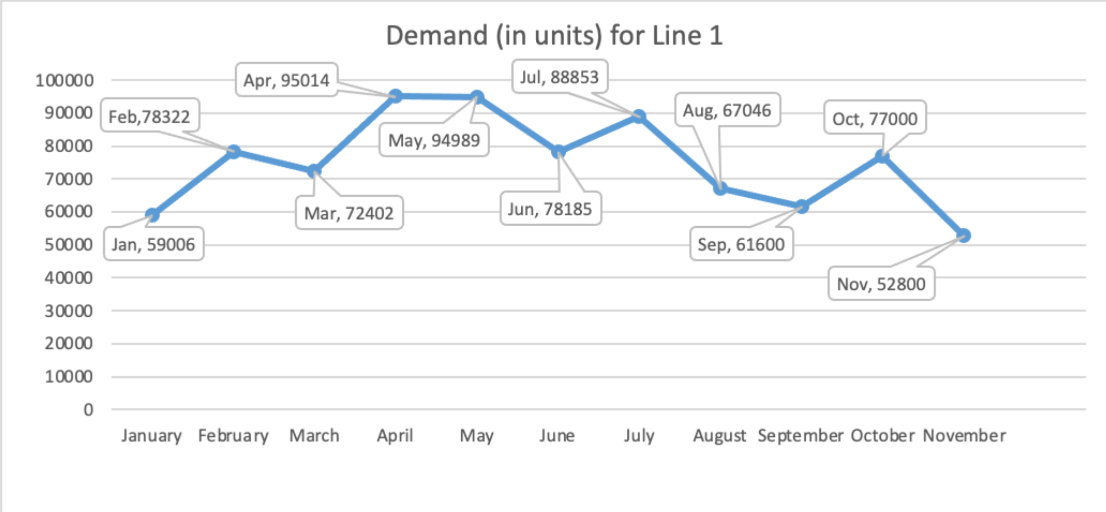
By 2013, Mexico had 267 aerospace companies, approximately 200 of which were concentrated in five northern states. The states with the highest number of aerospace firms were Baja California (59), Sonora (45), Chihuahua (32), Querétaro (33), and Nuevo León (32) [3]. Of the total number of identified companies, 80% were manufacturers, while the remainder offered engineering design services as well as maintenance, repair, and operations.

Specifically, Sonora recorded investments totaling 14.3 million USD in 2023 for aerospace equipment manufacturing, reflecting the sector's continued growth. According to the Ministry of Economy, between 2006 and 2023, Foreign Direct Investment (FDI) in the Mexican aerospace sector amounted to 3.626 billion USD. Of this figure, Sonora received 283.22 million USD, representing 8.1% of the national total [4]. The same author notes that Sonora's prominent position is due to its strategic location near the United States border, its skilled labor force, and its modern infrastructure—key factors that have strengthened its competitiveness in the aerospace industry.

The company under study continuously conducts studies to update the standard time for each activity in its process, determine the number of operators needed per station, and thereby allocate workloads. Other factors that have motivated these studies include the introduction of new product families or prototypes, new technology and operations, changes to procedures, low productivity, and waste reduction in processes, among others.

Collected data exemplifies an increase in demand during April and May, with 95,014 and 94,989 units, respectively. During this period, the line's workforce increased from 20 to 24 operators, representing a 20% increase. Figure 1 below shows the demand pattern for Line 4.

Figure 1: Demand in units for Line 4

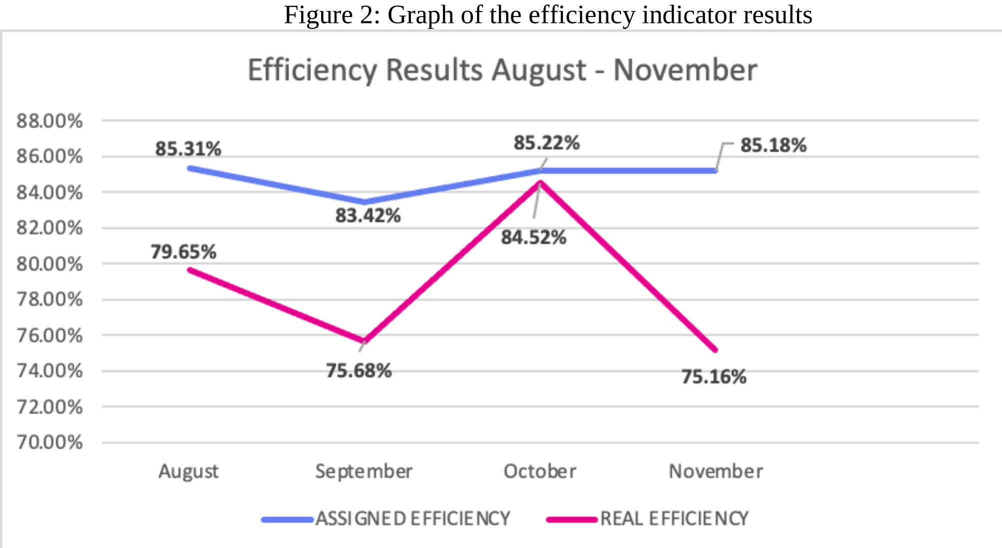


The figure above shows an increase in demand in May; however, starting in July, there was a decrease in production requirements, while the workforce remained at 24 employees. Furthermore, in October, the Vision System was integrated into the production line, causing complications in operator allocation. Therefore, it was decided to add two more operators to the staff, increasing the total from 24 to 26.

Another aspect that has been affected is overtime pay for the line. According to data provided by the organization, a total of 638 additional hours were paid during the last quarter of the year, with an approximate value of $2,000. Despite these figures, the overall cycle time, an indicator that measures the processing time for an order, has increased to 2.43 days compared to an expected value of 1.7 days. An analysis of the production line was conducted at the company during January and February, revealing an average of one day of inventory in the racks of the Gluing 1, Grinding, Electrical Testing, and Gluing 2 stations.

In August, the line's efficiency reached 79%, according to data provided by the area supervisor, representing a total of 70,298 pieces produced. The following month, production dropped to 58,883 pieces, requiring a total of 3,623 production hours, with an efficiency of 75.68%, falling below the target of 85%. A graph showing the efficiency achieved during the last six months of the current year is shown below.

Figure 2: Graph of the efficiency indicator results



Production line 4 in the subassembly area has deficiencies in personnel time management, as the number of operators per station has been assigned empirically. This means that as production demand peaks, workers have been added to the line, or workers from other lines have been reassigned to support the activities. This demonstrates a lack of control over the labor required to achieve daily, weekly, and monthly production targets.

This phenomenon has also generated a downward trend in process efficiency, from 73.77% to the desired minimum of 80%, since the increase in man-hours negatively impacts this indicator. Based on the above, the following research question is posed: ¿What will be the workload of the operators on production line 4 in the subassembly area?

Objective: Determine the workload of the production line operators in the area under study in order to increase their efficiency by at least 17%.This project aims to identify all work elements present in each specific operation, obtain the processing times for part numbers, and determine, based on these data, the ideal number of operators per station to increase efficiency.

Without conducting this study, a downward trend is projected for the line's labor efficiency indicator, as the ideal number of operators per station and processing times will remain unknown. This could lead to incorrect personnel allocation, increasing man-hours, potentially resulting in overpayment, and yielding an unfounded capacity calculation.

Operators will benefit from a more balanced workload and less idle time. The company will also benefit from the project by being able to determine the number of operators required per station based on cycle times, achieving greater process flow without impacting labor efficiency.

II. Method

The phases of the procedure correspond to a combination of the different steps for addressing a line balancing problem offered in the methodologies of [5], [6]and finally[7].

1. **Analyze the connector subassembly process:** To begin the project, the production mix was characterized. First, a list of part numbers was compiled, and the sequence of operations for each part number was identified. Following this, the production line was observed, and a list of the elements observed in each operation was compiled and classified according to [7].
2. **Determine the cycle time:** To calculate the cycle time, it was necessary to time all the elements of each operation for each part number 10 times, and then add an adjustment. The equation for calculating cycle time was as follows:

   (1) Cycle time = ∑minimum cycle time + ∑minimum periodic time

   Where:

   (2) Minimum cycle time: Minimum cycle time + Adjustment
   (3) Minimum periodic time: Minimum periodic time + Adjustment
   (4) Maximum: Maximum time among the 10 element records
   (5) Minimum: Minimum time among the 10 element records
   (6) Element fluctuation: Maximum - Minimum
   (7) Adjustment: (Element fluctuation) (Element cycle time fluctuation) / (∑Element fluctuation)
   (8) Element cycle time: ∑Times from element 1 to time n

Following the calculation of the cycle times for each part number, a reference matrix was constructed to determine the percentage of demand each part number represents in the total production mix. This is because the operation will have a different cycle time per part, and each part impacts the process differently depending on its demand. The contribution percentage for each part number is calculated as follows:

(9) % Contribution = (Demand for Part Number) / (∑Demand) x 100

Once this is done, a weighted time table was created using the followingequation:

(10) Weighted Cycle Time per Part = (Cycle Time * % Contribution) + (Periodic Time * % Contribution) + (Adjustment * % Contribution)

3. Determine Takt Time. To determine the takt time, it was necessary to obtain the demand for parts per part number and establish the available operating time for connector line 4. The takt time was determined using the following equation according to [6]:

   (11) Takt time = (Available time in seconds) / (Demand for parts in units)

4. Operator Balancing Chart. Once the weighted cycle times per station were determined, the number of operators was calculated using the following equation:

   (12) Number of Operators = (Weighted Cycle Time of the Station) / (Takt Time)

5. **Operation Balancing.** In this phase, the possibility of increasing an operator's workload was analyzed, and activities were added to their tasks with the intention of minimizing the number of operators required per station. This resulted in less idle time and greater labor efficiency.
6. **Evaluate the Efficiency of the Balancing Achieved.** Once the workloads were balanced across the different stations of the connector subassembly process on line 4, the line efficiency was calculated using the following equation:

   (13) Line Efficiency = (Hours Produced) / (Hours Worked)

Where the output mentioned by Pascal (2015) is interpreted by the organization as hours produced, calculated as follows:

(14) Hours Produced = Weighted Standard * Pieces Produced

The weighted standard is the weighting of the total weighted times in hours per station, presented by the following equation:

(15) Weighted Standard = (∑Weighted Station Times) / 3600

III. Results

In the important results, the clipping station times were obtained for the main part number. Fig. 3 presents the times corresponding to each cyclic element, as well as the periodic elements.

Figure 3: Clipe observation sheet for part number.

Operator Name: Date and Time Performed by: Process: Manual Clip
Part No.: EPXBEP3PA Description: No. of Cavities: 3 H

#	Components	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustment	Min. Time
1	Take tray insulators (WIP)	1.21	1.2	1.08	1.23	1.61	1.39	1.42	1.02	1.22	1.18	1.61	1.08	0.55	0.31	1.37
2	Clip insulators + push (3 cavities)	7.29	8.93	7.85	8.94	8.22	8.34	7.98	7.02	8.66	7.82	8.94	6.34	1.51	0.86	7.2
3	Fix with fixture	9.22	11.02	10	9.45	8.44	9.97	9.06	10.41	10.1	9.75	11.02	9.06	1.96	1.12	10.18
4	Place insulators in PT trays	1.46	1.09	1.27	1.72	1.42	1.32	1.61	1.98	1.29	1.48	1.72	1.27	0.45	0.26	1.53
	Total elemental cycle time	19.18	20.24	20.18	19.54	17.89	19.02	19.87	20.08	19.27	20.21	22.2	17.73	2.55		20.28
#	**Periodic work**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Max**	**Min**	**Fluct.**	**Adjustment**	**Min. Time**
1	Go to the rack for the work order and its components, check the work order and record data (set up)	0.96	0.53	0.52								0.96	0.53	0.02	0.02	0.56
2	Check MES to look for the tool to use (Manual clip 1)	0.89	0.92	0.88								0.92	0.89	0.03	0.03	0.92
3	Search for manual tool	1.17	1.12	1.25								1.25	1.17	0.08	0.08	1.25
4	Take and clip an insulator, clip inspection (set up)	2.87	0.83	0.9								2.87	0.9	1.97	1.93	2.83
5	Quality inspection to release order	0.33	0.34	0.35								0.35	0.34	0.01	0.01	0.35
	Total elemental cycle time	5.81	3.74	3.9								5.94	3.83	2.07		5.9
															CYCLE TIME	26.2

The following fig. 4, shows the observed elementary times:

Figure 4: Filling in the elemental time on the observation sheet.

Operator Name: Date and Time Performed by: Process: Manual Clip
Part No.: EPXBEP3PA Description: No. of Cavities: 3 H

#	Components	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustment	Min. Time
1	Take tray insulators (WIP)	1.21	1.2	1.08	1.23	1.61	1.39	1.42	1.02	1.22	1.18	1.61	1.08	0.55	0.31	1.37
2	Clip insulators + push (3 cavities)	7.29	8.93	7.85	8.94	8.22	8.34	7.98	7.02	8.66	7.82	8.94	6.34	1.51	0.86	7.2
3	Fix with fixture	9.22	11.02	10	9.45	8.44	9.97	9.06	10.41	10.1	9.75	11.02	9.06	1.96	1.12	10.18
4	Place insulators in PT trays	1.46	1.09	1.27	1.72	1.42	1.32	1.61	1.98	1.29	1.48	1.72	1.27	0.45	0.26	1.53
	Total elemental cycle time	19.18	20.24	20.18	19.54	17.89	19.02	19.87	20.08	19.27	20.21	22.2	17.73	2.55		20.28
#	**Periodic work**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Max**	**Min**	**Fluct.**	**Adjustment**	**Min. Time**
1	Go to the rack for the work order and its components, check the work order and record data (set up)	0.96	0.53	0.52								0.96	0.53	0.02	0.02	0.56
2	Check MES to look for the tool to use (Manual clip 1)	0.89	0.92	0.88								0.92	0.89	0.03	0.03	0.92
3	Search for manual tool	1.17	1.12	1.25								1.25	1.17	0.08	0.08	1.25
4	Take and clip an insulator, clip inspection (set up)	2.87	0.83	0.9								2.87	0.9	1.97	1.93	2.83
5	Quality inspection to release order	0.33	0.34	0.35								0.35	0.34	0.01	0.01	0.35
	Total elemental cycle time	5.81	3.74	3.9								5.94	3.83	2.07		5.9
															CYCLE TIME	26.2

The following shows the calculated “elementary time” of the first observation:
Elementary cycle time: 1.21 + 7.29 + 9.22 + 1.46 = 19.18 sec.

Next, the maximum times for each element were determined, as well as the minimum times within the 10 recordings of each individual element. The maximum and minimum times for each element were obtained using equation (4) and(5):

Figure 5: Filling in the MAX and MIN values on the observation sheet.

Operator Name:				**Date and Time**		**Performed by:**		**Process:**		**Manual Clip**						
Part No.: EPXBEP3PA				**Description:**		**No. of Cavities: 3 H**										
#	**Components**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Max**	**Min**	**Fluct.**	**Adjustment**	**Min. Time**
1	Take tray insulators (WIP)	1.21	1.2	1.08	1.23	1.61	1.39	1.42	1.02	1.22	1.18	1.61	1.08	0.55	0.31	1.37
2	Clip insulators + push (3 cavities)	7.29	8.93	7.85	8.94	8.22	8.34	7.98	7.02	8.66	7.82	8.94	6.34	1.51	0.86	7.2
3	Fix with fixture	9.22	11.02	10	9.45	8.44	9.97	9.06	10.41	10.1	9.75	11.02	9.06	1.96	1.12	10.18
4	Place insulators in PT trays	1.46	1.09	1.27	1.72	1.42	1.32	1.61	1.98	1.29	1.48	1.72	1.27	0.45	0.26	1.53
	Total elemental cycle time	19.18	20.24	20.18	19.54	17.89	19.02	19.87	20.08	19.27	20.21	22.2	17.73	2.55		20.28
#	**Periodic work**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Max**	**Min**	**Fluct.**	**Adjustment**	**Min. Time**
1	Go to the rack for the work order and its components, check the work order and record data (set up)	0.96	0.53	0.52								0.96	0.53	0.02	0.02	0.56
2	Check MES to look for the tool to use (Manual clip 1)	0.89	0.92	0.88								0.92	0.89	0.03	0.03	0.92
3	Search for manual tool	1.17	1.12	1.25								1.25	1.17	0.08	0.08	1.25
4	Take and clip an insulator, clip inspection (set up)	2.87	0.83	0.9								2.87	0.9	1.97	1.93	2.83
5	Quality inspection to release order	0.33	0.34	0.35								0.35	0.34	0.01	0.01	0.35
	Total elemental cycle time	5.81	3.74	3.9								5.94	3.83	2.07		5.9
															CYCLE TIME	26.2

The next step in completing the observation sheet for the connector clipping operation was to obtain the fluctuation for each element. Understanding fluctuation is important because, unlike traditional time studies where different types of allowances and performance ratings are configured, in this organization it is understood as the difference between the maximum and minimum times in a set of records. This variation is due to various factors that cause a delay in the execution of the element. This concept is applicable in modern time studies to both elements and elemental cycle times, and can originate from different sources, taking into account both operator and analyst error. The fluctuation of each element was determined as shown in the following figure, using equation (6):

Figure 6: Filling in the Fluctuation section on the observation sheet.

Operator Name:				**Date and Time**		**Performed by:**		**Process:**		**Manual Clip**						
Part No.: EPXBEP3PA				**Description:**		**No. of Cavities: 3 H**										
#	**Components**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Max**	**Min**	**Fluct.**	**Adjustment**	**Min. Time**
1	Take tray insulators (WIP)	1.21	1.2	1.08	1.23	1.61	1.39	1.42	1.02	1.22	1.18	1.61	1.08	0.55	0.31	1.37
2	Clip insulators + push (3 cavities)	7.29	8.93	7.85	8.94	8.22	8.34	7.98	7.02	8.66	7.82	8.94	6.34	1.51	0.86	7.2
3	Fix with fixture	9.22	11.02	10	9.45	8.44	9.97	9.06	10.41	10.1	9.75	11.02	9.06	1.96	1.12	10.18
4	Place insulators in PT trays	1.46	1.09	1.27	1.72	1.42	1.32	1.61	1.98	1.29	1.48	1.72	1.27	0.45	0.26	1.53
	Total elemental cycle time	19.18	20.24	20.18	19.54	17.89	19.02	19.87	20.08	19.27	20.21	22.2	17.73	2.55		20.28
#	**Periodic work**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Max**	**Min**	**Fluct.**	**Adjustment**	**Min. Time**
1	Go to the rack for the work order and its components, check the work order and record data (set up)	0.96	0.53	0.52								0.96	0.53	0.02	0.02	0.56
2	Check MES to look for the tool to use (Manual clip 1)	0.89	0.92	0.88								0.92	0.89	0.03	0.03	0.92
3	Search for manual tool	1.17	1.12	1.25								1.25	1.17	0.08	0.08	1.25
4	Take and clip an insulator, clip inspection (set up)	2.87	0.83	0.9								2.87	0.9	1.97	1.93	2.83
5	Quality inspection to release order	0.33	0.34	0.35								0.35	0.34	0.01	0.01	0.35
	Total elemental cycle time	5.81	3.74	3.9								5.94	3.83	2.07		5.9
															CYCLE TIME	26.2

Fig. 6, shows that there is greater fluctuation in the cyclic elements of the clipping and fixture fixing operations, with 1.51 and 1.96 seconds, respectively. For example, for cyclic element #1, "Take tray insulators," the fluctuation corresponds to the MAX (1.61 seconds) minus the MIN (1.06 seconds), resulting in a difference of 0.55 seconds.

To calculate the adjustment for element #1, the cyclic function "Retrieve tray insulators," as showbelow:

$$Adjustment: \frac{(0.55)(2.55)}{4.47} = 0.31 \text{ segundos}$$

Figure 7: Calculation of the adjustment on the observation sheet

Operator Name: Date and Time Performed by: Process: Manual Clip
Part No.: EPXBEP3PA Description: No. of Cavities: 3 H

#	Components	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustment	Min. Time
1	Take tray insulators (WIP)	1.21	1.2	1.08	1.23	1.61	1.39	1.42	1.02	1.22	1.18	1.61	1.08	0.55	0.31	1.37
2	Clip insulators + push (3 cavities)	7.29	8.93	7.85	8.94	8.22	8.34	7.98	7.02	8.66	7.82	8.94	6.34	1.51	0.86	7.2
3	Fix with fixture	9.22	11.02	10	9.45	8.44	9.97	9.06	10.41	10.1	9.75	11.02	9.06	1.96	1.12	10.18
4	Place insulators in PT trays	1.46	1.09	1.27	1.72	1.42	1.32	1.61	1.98	1.29	1.48	1.72	1.27	0.45	0.26	1.53
	Total elemental cycle time	19.18	20.24	20.18	19.54	17.89	19.02	19.87	20.08	19.27	20.21	22.2	17.73	2.55		20.28
#	Periodic work	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustment	Min. Time
1	Go to the rack for the work order and its components, check the work order and record data (set up)	0.96	0.53	0.52								0.96	0.53	0.02	0.02	0.56
2	Check MES to look for the tool to use (Manual clip 1)	0.89	0.92	0.88								0.92	0.89	0.03	0.03	0.92
3	Search for manual tool	1.17	1.12	1.25								1.25	1.17	0.08	0.08	1.25
4	Take and clip an insulator, clip inspection (set up)	2.87	0.83	0.9								2.87	0.9	1.97	1.93	2.83
5	Quality inspection to release order	0.33	0.34	0.35								0.35	0.34	0.01	0.01	0.35
	Total elemental cycle time	5.81	3.74	3.9								5.94	3.83	2.07		5.9
															CYCLE TIME	26.2

Following the adjustment calculation, the minimum cycle time of each element was determined using equation (2). To calculate the minimum time for the cyclic element #1 “Retrieve tray insulators”, the following operation must be performed: Minimum cyclic time: 1.06+0.31=1.37 seconds.

Figure 8: Calculation of the adjustment on the observation sheet.

Operator Name: Date and Time Performed by: Process: Manual Clip
Part No.: EPXBEP3PA Description: No. of Cavities: 3 H

#	Components	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustmen	Min. Time
1	Take tray insulators (WIP)	1.21	1.2	1.08	1.23	1.61	1.39	1.42	1.02	1.22	1.18	1.61	1.08	0.55	0.31	1.37
2	Clip insulators + push (3 cavities)	7.29	8.93	7.85	8.94	8.22	8.34	7.98	7.02	8.66	7.82	8.94	6.34	1.51	0.86	7.2
3	Fix with fixture	9.22	11.02	10	9.45	8.44	9.97	9.06	10.41	10.1	9.75	11.02	9.06	1.96	1.12	10.18
4	Place insulators in PT trays	1.46	1.09	1.27	1.72	1.42	1.32	1.61	1.98	1.29	1.48	1.72	1.27	0.45	0.26	1.53
	Total elemental cycle time	19.18	20.24	20.18	19.54	17.89	19.02	19.87	20.08	19.27	20.21	22.2	17.73	2.55		20.28
#	Periodic work	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustmen	Min. Time
1	Go to the rack for the work order and its components, check the work order and record data (set up)	0.96	0.53	0.52								0.96	0.53	0.02	0.02	0.56
2	Check MES to look for the tool to use (Manual clip 1)	0.89	0.92	0.88								0.92	0.89	0.03	0.03	0.92
3	Search for manual tool	1.17	1.12	1.25								1.25	1.17	0.08	0.08	1.25
4	Take and clip an insulator, clip inspection (set up)	2.87	0.83	0.9								2.87	0.9	1.97	1.93	2.83
5	Quality inspection to release order	0.33	0.34	0.35								0.35	0.34	0.01	0.01	0.35
	Total elemental cycle time	5.81	3.74	3.9								5.94	3.83	2.07		5.9
															CYCLE TIME	26.2

Subsequently, the sum of all cyclic elements is calculated, as well as the sum of all periodic elements. The result of this sum is the "Cycle Time," which is the actual time the operator spends performing all the elements that make up the process in the operation. The cycle time is calculated using equation (1) and is shown in Fig. 9.

Figure 9: Cycle Time Calculation on the Observation Sheet.

Operator Name: Date and Time Performed by: Process: Manual Clip
Part No.: EPXBEP3PA Description: No. of Cavities: 3 H

#	Components	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustment	Min. Time
1	Take tray insulators (WIP)	1.21	1.2	1.08	1.23	1.61	1.39	1.42	1.02	1.22	1.18	1.61	1.08	0.55	0.31	1.37
2	Clip insulators + push (3 cavities)	7.29	8.93	7.85	8.94	8.22	8.34	7.98	7.02	8.66	7.82	8.94	6.34	1.51	0.86	7.2
3	Fix with fixture	9.22	11.02	10	9.45	8.44	9.97	9.06	10.41	10.1	9.75	11.02	9.06	1.96	1.12	10.18
4	Place insulators in PT trays	1.46	1.09	1.27	1.72	1.42	1.32	1.61	1.98	1.29	1.48	1.72	1.27	0.45	0.26	1.53
	Total elemental cycle time	19.18	20.24	20.18	19.54	17.89	19.02	19.87	20.08	19.27	20.21	22.2	17.73	2.55		**20.28**
#	Periodic work	1	2	3	4	5	6	7	8	9	10	Max	Min	Fluct.	Adjustment	Min. Time
1	Go to the rack for the work order and its components, check the work order and record data (set up)	0.96	0.53	0.52								0.96	0.53	0.02	0.02	0.56
2	Check MES to look for the tool to use (Manual clip 1)	0.89	0.92	0.88								0.92	0.89	0.03	0.03	0.92
3	Search for manual tool	1.17	1.12	1.25								1.25	1.17	0.08	0.08	1.25
4	Take and clip an insulator, clip inspection (set up)	2.87	0.83	0.9								2.87	0.9	1.97	1.93	2.83
5	Quality inspection to release order	0.33	0.34	0.35								0.35	0.34	0.01	0.01	0.35
	Total elemental cycle time	5.81	3.74	3.9								5.94	3.83	2.07		**5.9**
															CYCLE TIME	**26.2**

In Fig. 9, the cycle time for part number EPXBEP3PA in the clipping operation is shown. This is made up of the sum of the cycle time (20.28 seconds) and the periodic time (5.90 seconds) giving a total of 26.20 seconds.

After determining the cycle time and creating the weighting matrix for calculating the percentage of demand, the takt time was obtained considering a 12-hour shift, subtracting 60 minutes for meals and periodic breaks, as well as 30 minutes for personal needs. Additionally, two shifts per day were considered, covering four full days (Monday to Thursday) and one and a half days (Friday, Saturday, and Sunday). This totals 115.5 hours per week, equivalent to 415,800 seconds. Regarding demand, there is a total of 60,600 units for the monthly period, divided by the four weeks in the period, resulting in a total of 15,150 units per week. The takt time calculation is then performed:

Takt time = (415,800.00 seconds) / (15,150 pieces) = 27.45 seconds per piece

The calculation obtained with the equation above dictates the frequency at which a piece must be produced on the subassembly line to meet customer demand in a 10.5-hour shift.Once the takt time was obtained, the number of operators (see Table 1) required was determined based on the cyclic weighted times, the periodic weighted times, and the fluctuations.

Table 1: Calculation of operator requirements

Line 4	Cyclical	Periodic	Fluctuation	Takt time	Operators
Clip (Automatic/Mixed/Manual)	29.16	6.19	11.06	27.45	1.69
Vision Camera	8.69	4.37	2.51	27.45	0.57
Bonding #1	11.88	5.70	4.19	27.45	0.79
Clamping #1	8.64	0.75	2.30	27.45	0.43
Unclamping #1	9.02	0.34	0.82	27.45	0.37
Grinding	10.06	4.26	1.19	27.45	0.56
Electrical Testing	12.55	4.26	1.19	27.45	0.56
Bonding #2 (Tecaprint)	7.13	1.92	2.45	27.45	0.42
Bonding #2	7.70	6.12	2.18	27.45	0.58
Clamping #2	11.16	4.23	4.23	27.45	0.71
Unclamping #2	17.03	3.47	5.15	27.45	0.93
Cavity Marking	12.35	3.91	4.60	27.45	0.76
Laser	6.82	3.53	1.02	27.45	0.41
Final Inspection	7.10	2.76	1.85	27.45	0.43
Packaging	4.24	3.67	3.70	27.45	0.42

The table above shows that the workstations require fewer than one operator, with the exception of the clipping and cavity marking stations. While these stations could not meet production demand with a single operator, they also do not appear to be significantly underutilized for adding one more operator. Table 2, below shows the operator allocation.

Table 2: Operator Assignment

Line 4	Assigned
Clip (Automatic/Mixed/Manual)	2
Vision Camera	1
Bonding #1	1
Clamping #1	0.5
Unclamping #1	0.5

Grinding	1
Electrical Testing	1
Bonding #2(Tecaprint)	1
Bonding #2	0.5
Clamping #2	0.5
Unclamping #2	1
Cavity Marking	1
Laser	1
Final Inspection	1
Packaging	1
TOTAL	14

Table 3 presents a comparison of the previous and current state of the production line, considering the merging of several stations and the reduction of operators:

Table 3: Before and after line 4.

Indicator	Before balancing	After balancing
Number of Operators	14	11
Efficiency	73.77%	91.25%

As can be seen in the table 3, the crew of line one connector subassembly went from having 14 to 11 operators, which implies a reduction of 17% in labor costs and an increase of 17.48% with respect to efficiency.

IV. Conclusion

In conclusion, the results demonstrate a significant improvement in operational performance, evidenced by the 17.48% increase in the established indicator and the reduction of 2.5 operators without compromising process flow continuity. These actions effectively minimized fluctuations in critical stations and eliminated overtime costs, thereby strengthening overall process efficiency. Furthermore, the need to retain specialized personnel in stations that require advanced technical skills and strict machine times, such as the grinding area, is reaffirmed. The proposed recommendations—focused on operational standardization and the reduction of setup times through Lean tools such as 5S, waste analysis, and SMED—are essential for addressing seasonal demand variations. Finally, operator training in joint stations and the optimization of cycle times enhance the system's responsiveness, preventing unnecessary increases in staffing and promoting long-term operational sustainability.

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