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Planning and implementation of a study of times and methods in the Packaging Logistics Center (PLC) of industrial gas - analysis and standardization of production: A case study

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Abstract

The industrial gasification operations sector has transformed the logistics of industrial processes in the production, distribution and supply of gas to customers, as a result of increased demand and market competitiveness. In the health sector, this type of behavior occurs on a daily basis, in order to meet the demand for medical gas (O_2) supply in hospitals. The present investigation offers a proposal for methodological-investigative-mixed development, in relation to the study of times and methods focused on a gas supply company, in an effort to standardize processes. This is presented in five main phases: 1) Initial production diagnosis, with the analysis of the current productive behavior; 2) characterization and planning of the production proposal of the company being investigated; 3) purification and statistical treatment of information, analysis and sample intervention; 4) matrix construction and generation of production standards; 5) analysis of the results and presentation of the value proposition, through the application of engineering strategies and the cost-benefit ratio. The results obtained from the present investigation made it possible to optimize the operational times of the gas inspection process, filling of rack cylinders and mobile gas pumping by 14.72%, 6.46% and 8.02%, respectively.

Key words

Study of times and methods, standard time, medicinal gas (O_2), work design, production, industrial cost-benefit analysis.

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This research examines the operating system at the Packaging Logistics Center (PLC) in the supply activities for bottled gas cylinders

1. Introduction

Industrial processes within organizations have a particular characteristic, namely, the constant demand for the energy required for the correct fulfillment of the processes involved in the transformation of raw materials into finished products. This type of fuel, in general, is characterized by being non-renewable, which makes it an interesting product to be considered in order to guarantee its use by future generations (Oliver & Mason, 2018). Based on this characteristic, investigations around the world are developing studies and strategies to improve the factors of effectiveness and efficiency for this type of industrial supply.

One of the consumable goods used in this type of industry, which constitutes the subject of our present research, is what is known as Medicinal Gas (O_2), a product in high demand by hospitals around the country. The integration of the finished product into the supply chain and the correct transport and distribution logistics strategy play an essential role in the correct functioning of the gasification operating system. The present research considers and analyzes the operating system used by the *Packaging Logistics Center* (PLC) in the supply activities for gas cylinders (bottling), and a study is conducted on the work performed during the operating processes and their correct execution, based on the times and methods study methodology.

The current problem presented by the *Packaging Logistics Center* (PLC) is the lack of a system for controlling, monitoring and standardizing the processing times for each of the activities that form part of the current logistics system. The opportunities for improvement and identification of non-productive times are studied and identified within the study and a proposal for an improvement plan is made, based on a brainstorming strategy, along with a proposal for the improvement of the associated techniques. The current productivity indicators quantify the information on finished products for each of the study areas. However, the lack of identification of the related activities as elements for the correct

The integration of the finished product into the supply chain and the transport and distribution logistics strategy play an essential role in the functioning of the gasification operating system

measurement of each of them necessitates the generation of more specific lines of measurement in order to identify the causes of non-productive times for the associated operations.

The present research is carried out in 5 main phases, the first of which is the *initial production diagnosis*, with the characterization of the production times registered by the organization and the measurement of the company's performance indicators for each of the study activities; in the second phase, the *characterization and planning of the production proposal* is performed, in which the main elements that make up the times study, needs identification and measurement elements are described; the third element refers to the *debugging and statistical processing of the data*, in which the normal behavior of the data is analyzed, the control limits are identified and the ideal sample sizes are determined in order to statistically guarantee the reliability of the study sample; the fourth element is known as the *elaboration of the matrix for the times and methods study and the generation of production standards;* this is based on the generation of the basic and standard observed time, considering the supplements of each of the activities being studied, as well as the characterization and the work rituals of the operators. Finally, the analysis of the results obtained and presentation of the value proposal is carried out, with the generation of the production indicators according to the times and methods study, comparative analysis with the organization's current indicators and generation of the value proposal, with the new production values according to the productivity of each of the departments in the study. The results of the present research allowed the identification of improvements to the work study, the characterization and determination of the activities that generate value within the organization's logistic process, the generation of a technological matrix to measure the performance of the activities, the generation of production standards, the study of causes of non-productive times and the implementation of proposals for improvement.

2. Methodology and research development

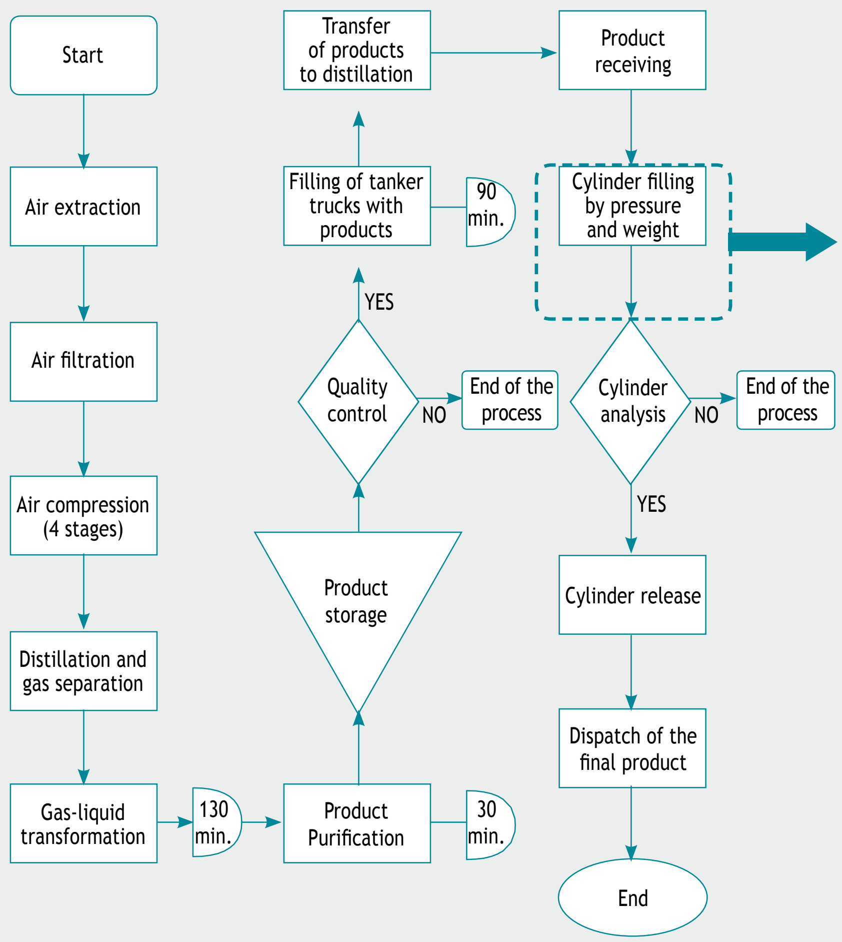
In this project, the methodology that has been developed consists of five phases, which were implemented over the course of 4 months. This information is presented below.

2.1. Phase I: Initial production diagnosis

During the first phase of the research process, the current production indicators were studied and the method of generating the data obtained was analyzed. A stopwatch was used to measure the times in order to analyze the Packaging Logistics Center (PLC); this procedure was carried out for each day, monthly, over the course of 6 months as the first step in the research and standardization of times. As a complement to the time recording, a direct observation was made to identify the main "non-productive" factors within each of the workstations: work ergonomics, product design, tolerances and specifications, the production process, tools and equipment, material handling and plant distribution. The description and characteristics of the data obtained are presented in Figure 1.

In the present research process, time information was collected for the rack cylinder filling, pipe quality inspection (cylinder analysis) and mobile gas pumping (filling of tanker trucks with products) activities. For each of the processes, the "qualified employees" were identified, characterized as being operators with average levels of production, a consistent level of work, knowledge of the activities carried out and a normal rate of work within the analyzed operating area (Niebel, Freivalds, Del, Ibarra & Ana, 2009).

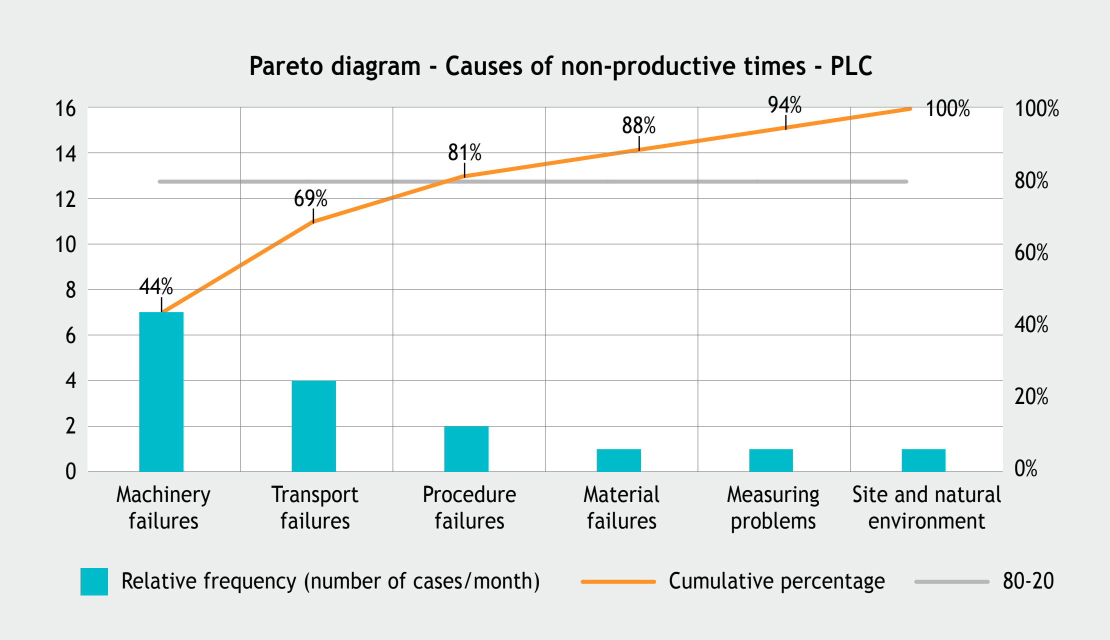
Figure 1
Description of the elements analyzed and example of data collection - Operator 6



No.	Type of product	Product Code	Branch	Verifying user	Production day analyzed	Day analyzed	Start time	End time	Total time (minutes)	Total time (hours)
1	Cylinder filling	11610595421	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	7:20:00 AM	7:28:00 AM	8.00	0.13
2	Cylinder filling	11608365461	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	7:45:00 AM	7:54:00 AM	9.00	0.15
3	Cylinder filling	1201142332	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	8:13:00 AM	8:20:00 AM	7.00	0.12
4	Cylinder filling	1170921686	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	8:35:58 AM	8:47:36 AM	11.63	0.19
5	Cylinder filling	1190747417	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	9:00:00 AM	9:11:00 AM	11.00	0.18
6	Cylinder filling	1190747417	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	9:15:48 AM	9:27:58 AM	12.17	0.20
7	Cylinder filling	1160815952	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	9:29:00 AM	9:38:00 AM	9.00	0.15
8	Cylinder filling	1200819011	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	9:58:12 AM	10:19:45 AM	21.55	0.36
9	Cylinder filling	1201107221	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	10:32:00 AM	10:41:00 AM	9.00	0.15
10	Cylinder filling	11807387791	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	10:54:00 AM	11:07:00 AM	13.00	0.22
11	Cylinder filling	1181322781	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	11:10:00 AM	11:20:00 AM	10.00	0.17
12	Cylinder filling	1181324766	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	11:22:00 AM	11:30:00 AM	8.00	0.13
13	Cylinder filling	1200855824	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	11:35:00 AM	11:42:00 AM	7.00	0.12
14	Cylinder filling	1200855824	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	11:44:00 AM	11:56:00 AM	12.00	0.20
15	Cylinder filling	1161116880	ANTIOQUÍA	Distribution Op 6	13	8/13/2019	1:05:00 PM	1:12:00 PM	7.00	0.12

In the present study, the main causes of non-productive time in the Packaging logistics process were analyzed and identified, as illustrated in Figure 2. The following 3 main shortcomings were identified within the process: First, *Machinery failures* (44% of non-productive causes), specifically in the rack cylinder filling activity, where the purge valves present deterioration, specifically due to the service life of this equipment. The above is presented based on the service life of the equipment and the lack of preventive maintenance, directly affecting the operating system and industrial process. This causes the workers to have to move to obtain a spare valve, affecting the filling process and its continuity.

Figure 2
Diagram of the causes of non-productive times - Packaging Logistics Center (PLC)



A second element identified within the processes is *transport failures* (25% of non-production causes); this situation occurs during the mobile gas pumping activity, as the result of the constant movement of the required cylinders from the production area to the distribution area, due to the lack of a ground pipeline transport system for this type of supply (O_2).The third element of non-productive times is due to *failures in operating procedures* (12% of non-productive causes), specifically for rack cylinder filling, pipe quality inspection and mobile gas pumping activities.

Based on the above information, the organization's administrative department has determined, together with the engineers from the operational area, the "rigid" time standards according to which the employee must perform the task on a daily basis and establishing the production and periodic monitoring indicators, as shown in Table 1. The processing times for each of the activities (total time in minutes) can be seen in the record for each area operator. For the present calculation, the maximum possible working time for each operator (minutes/day) is taken into account, according to their working hours (8 hours/day).

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Table 1
Production Indicator - Rack cylinder filling activity - 2018

Type of product	Product Code	Branch	Verifying user	Production day analyzed	Start time	End time	TOTAL TIME (minutes)	Minutes/ day	Average break (lunch time; break time)	Net time	Unit production/ day	Production indicator
Cylinder filling	1201037114	ANTIOQUÍA	Distribution Op	1	2:14:00 PM	2:25:00 PM	11.00	480	85	395	36	40
Cylinder filling	1201022214	ANTIOQUÍA	Distribution Op	5	2:32:00 PM	2:41:00 PM	9.00	480	85	395	44	
Cylinder filling	1161144444	ANTIOQUÍA	Distribution Op	7	2:45:00 PM	3:00:00 PM	15.00	480	85	395	26	
Cylinder filling	1161144444	ANTIOQUÍA	Distribution Op	9	3:03:00 PM	3:12:00 PM	9.00	480	85	395	44	
Cylinder filling	1191104847	ANTIOQUÍA	Distribution Op	11	3:13:00 PM	3:21:00 PM	8.00	480	85	395	49	
Cylinder filling	1191104847	ANTIOQUÍA	Distribution Op	15	3:25:00 PM	3:34:00 PM	9.00	480	85	395	44	
Cylinder filling	1191104847	ANTIOQUÍA	Distribution Op	18	3:36:00 PM	3:48:00 PM	12.00	480	85	395	33	
Cylinder filling	1191104847	ANTIOQUÍA	Distribution Op	21	3:50:00 PM	4:00:00 PM	10.00	480	85	395	40	
Cylinder filling	1201149661	ANTIOQUÍA	Distribution Op	24	4:01:00 PM	4:10:00 PM	9.00	480	85	395	44	
Cylinder filling	1201149661	ANTIOQUÍA	Distribution Op	27	4:12:00 PM	4:21:00 PM	9.00	480	85	395	44	
Cylinder filling	1181320461	ANTIOQUÍA	Distribution Op	30	4:24:00 PM	4:34:00 PM	10.00	480	85	395	39	

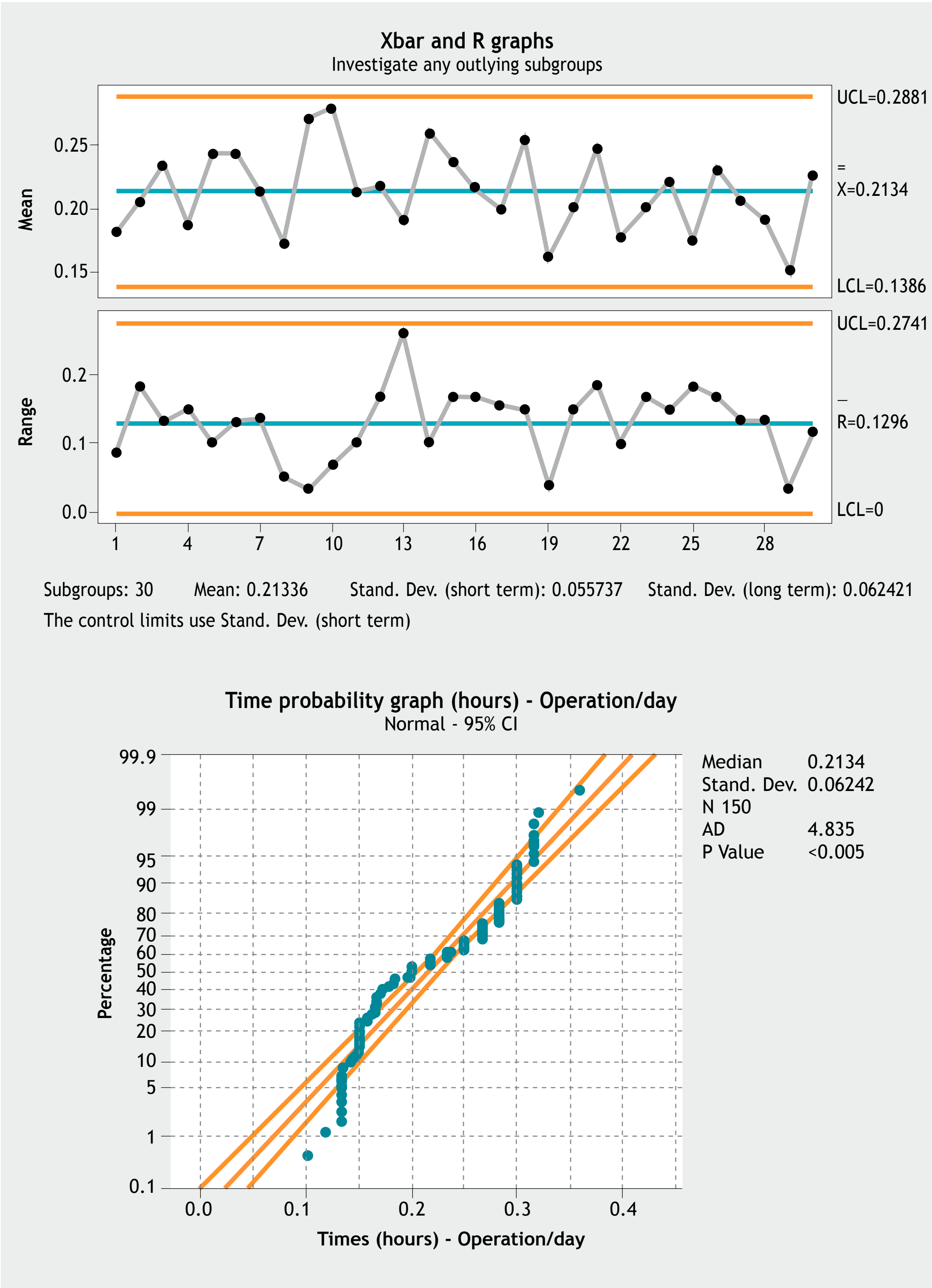
2.2. Phase II: Characterization and production planning

2.2.1. Identification of study data

The first analysis generated from the present research is the study of the data obtained as a result of productivity measurements in each of the analyzed areas. Once the study samples were obtained, a statistical analysis was carried out, with the aim of measuring their status, analyzing levels of dispersion and trends in relation to the normal behavior of the data, as shown in Figure 3.

In this graph, the ratio of the historical average processing time per day (hh/un) analyzed for employees performing the rack cylinder filling activity can be seen over a time interval of 30 days of production operation (*subgroups*). As can be seen, the data does not follow a pattern that can be associated with normal behavior (value $p<0.005$), which is caused by the lack of systematized procedures for the performance of the activities involved in each of the areas of study. According to the behavior of the data, the reference time values are within the related control intervals (UCL=0.2881; LCL=0.1386), evidencing that a statistical process control (SPC) is occurring (Cortés Martínez, Lobelles-Sardiñas & López-Bastida, 2019), since the associated values are within the range and interval of permissible values for the operating times by the operators. However, values with high variability, such as the value for day 13 (0.28 hrs), for example, can generate shortcomings in future time intervals in terms of the accuracy of the standardized processes, limiting the improvement and evolution of the design and the study of analyzed work. From the present information, improvement opportunities were identified in

Figure 3
Production Control Chart of the cylinder filling activity - Packaging Logistics Center (PLC)



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One of the techniques used was the standardization adjustment by calculating moving averages

relation to obtaining a standardized system: when analyzing the range of data (R=0.1296), it can be seen that there is a considerable range of data dispersion for the study sample. In accordance with the above, if the objective is to manage productivity factors within organizations, it is necessary to minimize the R value within the study in order to achieve specific measures of accuracy in the monitoring and control of the activities. The previous analysis is carried out for the complementary areas of pipe quality inspection and mobile gas pumping for each of the operators selected within the present investigation.

2.2.2. Initial processing of study information

A second element considered within this research is the processing and retrieval of study information. One of the exposed techniques used for the recovery of the data is known as the moving average standardization adjustment technique (least squares adjustment), as explained by (Rodríguez, Suazo & Santelices, 2016) and shown in Figure 4.

Figure 4
Example of least squares adjustment and the initial processing of information - Packaging Logistics Center (PLC)

Interaction 1							
Mean	**0.131976583**	0.05	0.03333333	0.01666667	0.01666667	0.05	0.03333333
Stand. Dev.	**0.249771339**	0.04547653	0.078361	0.06666667	0.05	0.8	0.05
Min.	−0.242680425	0.04547653	0.9	0.01666667	0.078361	0.01666667	0.03333333
Max.	0.506633592	0.04547653	0.01666667	0.03333333	0.6	0.04547653	0.04547653

Interaction 2							
Mean	**0.052640323**	0.05	0.03333333	0.01666667	0.01666667	0.05	0.03333333
Stand. Dev.	**0.035292945**	0.04547653	0.078361	0.06666667	0.05	0.13197658	0.05
Min.	−0.000299095	0.04547653	0.13197658	0.01666667	0.078361	0.01666667	0.03333333
Max.	0.1055797741	0.04547653	0.01666667	0.03333333	0.13197658	0.04547653	0.04547653

Interaction 3							
Mean	**0.04272329**	0.05	0.03333333	0.01666667	0.01666667	0.05	0.03333333
Stand. Dev.	**0.017943811**	0.04547653	0.078361	0.06666667	0.05	0.05264032	0.05
Min.	0.015807574	0.04547653	0.05264032	0.01666667	0.078361	0.01666667	0.03333333
Max.	0.069639007	0.04547653	0.01666667	0.03333333	0.05264032	0.04547653	0.04547653

An example of random data retrieval in the analyzed samples is illustrated in Figure 4. As can be seen, three reference values are presented that fall outside the data series and their control limits (0.6, 0.8, 0.9). According to the sample size of the study, the average and standard deviation are calculated, accompanied by the lower and upper limits in which they are found (Min., Max.). The interactions necessary for the retrieval of the values are performed until the entry of the related values in the lower and upper limit range is obtained, as can be seen in Interaction 3 for the related values.

2.3. Phase III: Statistical analysis of study information

The input data illustrated in Figure 4 allow us to identify the levels of dispersion associated with the study sample. To minimize this type of data characteristic and obtain values that fit the standards required for the present study (Niebel et al., 2009 and Arias-Gómez, Villasís-Keever & Miranda-Novales, n.d.) highlighted their importance as the first element in a pilot study, i.e., "random sampling and behavioral analysis of the present study data, so that all elements of the

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population have the same probability of being included in the study," according to the following equation:

$$n = \left[\frac{40 \sqrt{n' \sum X^2 - (\sum X)^2}}{\sum X} \right]^2 \qquad (1)$$

Where:

n = Sample size to be calculated
n' = Number of preliminary study observations
X = Value of observations
Σ Sum of the data

Equation number 1 makes it possible to determine, from a defined data set (random sample extraction), the sample size that must be considered in order to achieve statistically adequate levels of confidence in the experimental research work. From the mathematical calculation (Macgowan & Wong, 2017; Mellor et al., 2011) established that a 95% confidence level and a 5% margin of error can be achieved from the quantitative application presented in Equation 1. In the case of the present research, the extraction of 30 data items for each of the workers and respective sample size calculation is carried out, as illustrated in Figure 5.

Figure 5
Sample size calculation Operator 6 - rack cylinder filling - Packaging Logistics Center (PLC)

	User	n´	X	X^2		
Mean	Distribution Op 6	1	0.13	0.02		
0.16	Distribution Op 6	2	0.15	0.02		
Stand. Dev.	Distribution Op 6	3	0.12	0.01		
0.052296309	Distribution Op 6	4	0.19	0.04		
Max.	Distribution Op 6	5	0.18	0.03		
0.23586113	Distribution Op 6	6	0.20	0.04		
Min.	Distribution Op 6	7	0.15	0.02		
0.078972203	Distribution Op 6	8	0.36	0.13		
	Distribution Op 6	9	0.15	0.02		
	Distribution Op 6	10	0.22	0.05		
Day 1	Distribution Op 6	11	0.17	0.03		
	Distribution Op 6	12	0.13	0.02		
	Distribution Op 6	13	0.12	0.01		
	Distribution Op 6	14	0.20	0.04		
	Distribution Op 6	15	0.12	0.01		
	Distribution Op 6	16	0.15	0.02		
	Distribution Op 6	17	0.12	0.01		
	Distribution Op 6	18	0.13	0.02		
	Distribution Op 6	19	0.17	0.03		
	Distribution Op 6	20	0.13	0.02		
	Distribution Op 6	21	0.15	0.02		
	Distribution Op 6	22	0.25	0.06		
	Distribution Op 6	23	0.12	0.01		
	Distribution Op 6	24	0.13	0.02		
	Distribution Op 6	25	0.15	0.02		
	Distribution Op 6	26	0.12	0.01		
	Distribution Op 6	27	0.17	0.03		
	Distribution Op 6	28	0.12	0.01		
	Distribution Op 6	29	0.15	0.02		
	Distribution Op 6	30	0.08	0.01		
	Σ	30	4.72	0.82	n	171

Therefore, another 171 must be added to the 30 initial data items

Total n	201

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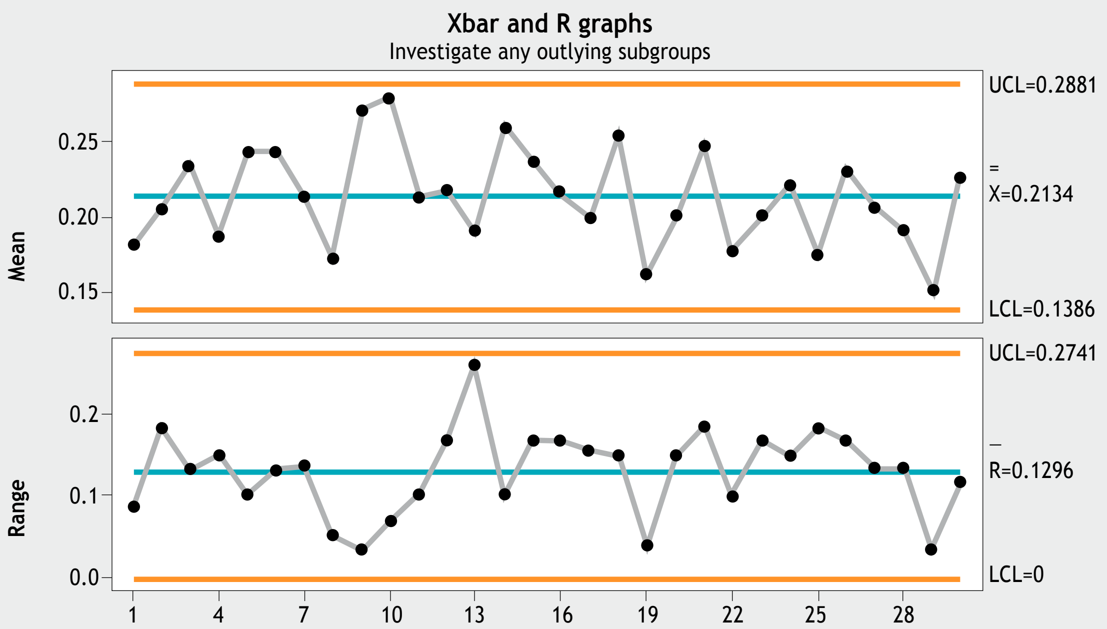
Observations of data behavior and study sample extraction in relation to processing times for rack filling, quality inspections and gas cylinder vacuum filling activities were performed for the study employees in the research time interval. Figure 5 shows an example of the 30 data items obtained for Operator 6 in the rack filling activity (value *X*). From this information and considering Equation 1, the sample size is calculated (n) to statistically guarantee the reliability of the data (95% confidence, 5% margin of error); it can be seen that 171 operating time records must be taken for Operator 6 to guarantee this statistical objective; as a conclusion, the total sample includes the 30 initial input data items and the 171 data items calculated from Equation 1, generating as a result the 201 total data items for the specific case of the work being studied (Total n).

Once the above observations are made, the total samples are taken and recorded (Total n) for the workers in the related areas, and the operating data for the period of time being analyzed (30 days for 6 months) are generated. This information is recorded again in the times study templates, and the new processing values for the activities are calculated. According to the present investigation and the processing times, the requested data are extracted directly from the records obtained from the biennial study of the field work, applying the times recorded for each operator. The processing values of the activities with their respective statistical processing are illustrated in Figure 6.

Figure 6
Production Control Chart of the cylinder filling activity - Packaging Logistics Center (PLC)

a) Initial proposal



Subgroups: 30 Mean: 0.21336 Stand. Dev. (short term): 0.055737 Stand. Dev. (long term): 0.062421
The control limits use Stand. Dev. (short term)

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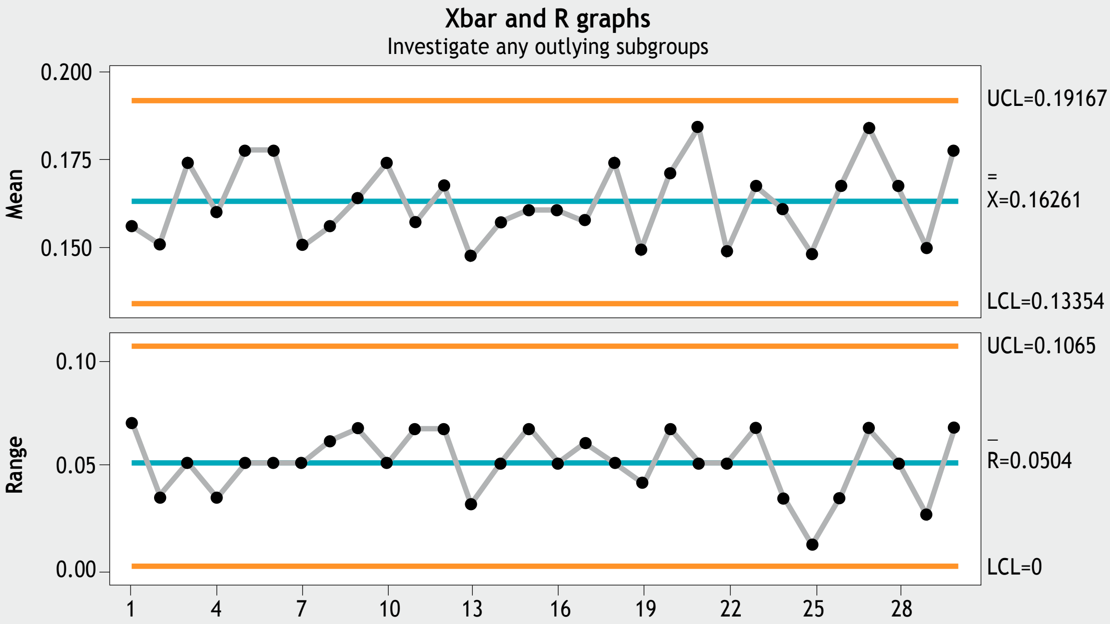
The initial (R=0.1296) and final (R=0.0504) dispersion curves are minimized by 61% in the analyzed data

Figure 6 (continued)

Production Control Chart of the cylinder filling activity - Packaging Logistics Center (PLC)

b) Final proposal (Application of statistical processing)



Subgroups: 30 Mean 0.16261 Stand. Dev. (short term):0.021663 Stand. Dev. (long term):0.022868
The control limits use Stand. Dev. (short term)

According to the previous results, it can be seen that the initial (R=0.1296) and final (R=0.0504) dispersion curves are minimized by 61%, according to the difference in the range of the analyzed data, once the statistical processing of the information has been carried out. This, in turn, results in the upper control limit (*UCL*=0.19167) and the lower control limit (*LCL*=0.13354) being lower than the results analyzed in the initial sample. The above is presented as a consequence of the sample size necessary to achieve the desired confidence levels, generating a more specific adjustment of the information obtained. In Figure 6, it can be seen how the production peaks (for example, the range values on day 13 and day 19) present a lower dispersion in relation to the data initially exposed, generating more precise and measurable values within these time periods. The opposite occurs on day 25, where the results point to an increase in the dispersion of data (range); this is caused by the variations in tasks that occur within the activities analyzed at the end of the month, as a result of the increase in activities within the logistics department and the generation of more work within the area of study.

2.4. Phase IV: Construction of the initial matrix: observed and basic times

One of the essential phases within this research is the generation of the times and methods study matrix for the analysis of the recorded data and obtaining the desired production standards for each of the areas analyzed. Records of the operating times for each of the activities are shown in Figure 7 for each of the operators, in each of the months analyzed.

Figure 7

Initial times and methods study matrix - Observed Time and Basic Time Calculation - Packaging Logistics Center (PLC)

ACTIVITY #	ELEMENT-PROCESS DESCRIPTION	OPERATOR	RATING SCALE	Times (hours) - Average Operation/day								F	N	Observed time	Basic time
				1	8	13	17	19	22	25	29				
1	Quality Inspection - piping	Distribution Op 1	1	0.24	0.24	0.26	0.27	0.28	0.26	0.27	0.28	1	65	0.26	0.26
2	Quality Inspection - piping	Distribution Op 2	1	0.24	0.25	0.25	0.24	0.25	0.24	0.23	0.25	1	81	0.24	0.24
3	Quality Inspection - piping	Distribution Op 3	1	0.21	0.24	0.26	0.28	0.25	0.25	0.25	0.23	1	104	0.25	0.25
4	Quality Inspection - piping	Distribution Op 4	1	0.23	0.22	0.25	0.24	0.21	0.21	0.24	0.20	1	137	0.23	0.23
5	Quality Inspection - piping	Distribution Op 5	1	0.22	0.24	0.24	0.25	0.26	0.27	0.23	0.24	1	120	0.24	0.24
6	Rack cylinder filling	Distribution Op 6	1	0.14	0.15	0.13	0.13	0.14	0.15	0.14	0.15	1	201	0.14	0.14
7	Rack cylinder filling	Distribution Op 7	1	0.13	0.12	0.15	0.14	0.13	0.12	0.15	0.16	1	317	0.14	0.14
8	Rack cylinder filling	Distribution Op 8	1	0.20	0.15	0.14	0.16	0.15	0.17	0.15	0.16	1	403	0.16	0.16
9	Rack cylinder filling	Distribution Op 9	1	0.16	0.18	0.15	0.16	0.16	0.13	0.15	0.14	1	92	0.15	0.15
10	Rack cylinder filling	Distribution Op 10	1	0.15	0.18	0.16	0.19	0.17	0.17	0.15	0.15	1	134	0.16	0.16
11	Mobile Gas pumping	Distribution Op 11	0.8	0.19	0.22	0.20	0.20	0.19	0.23	0.19	0.21	1	89	0.20	0.16
12	Mobile Gas pumping	Distribution Op 12	0.8	0.16	0.22	0.21	0.25	0.16	0.23	0.22	0.18	1	226	0.20	0.16
13	Mobile Gas pumping	Distribution Op 13	0.8	0.17	0.15	0.14	0.16	0.18	0.19	0.16	0.19	1	148	0.17	0.13
14	Mobile Gas pumping	Distribution Op 14	1	0.18	0.19	0.18	0.18	0.19	0.19	0.18	0.19	1	172	0.19	0.19
15	Mobile Gas pumping	Distribution Op 15	0.8	0.16	0.19	0.18	0.17	0.17	0.16	0.15	0.15	1	156	0.17	0.13

Figure 7 illustrates the template and time recording of each of the operators for one month of analysis. According to the information obtained previously, 5 operators were analyzed for each of the activities being studied (quality/piping inspection, rack cylinder filling, mobile gas pumping). Within the PLC logistics department, a study was carried out with the production manager in relation to the work rate of each of the study participants (*Assessment Scale*) in order to identify the speed with which the work is performed by each of the operators. The calculation of this type of elements is established according to the assessment of the processing of the activities and the historical records kept at the organization. The historical records of operating time *(Times (Hours) - average operation/day)* is illustrated for each of the employees on each of the days analyzed: the information is recorded for the 30 days of work of each of the operators during the 6 months of the study and is presented in a summarized form, as shown in the example of the present template, with the values referring to days 1, 8, 13, 17, 19, 22, 25 and 29 of work. The F value of the study refers to the number of units analyzed per unit of time; in this case each gas cylinder has its own independent operating time, so it is assigned a value of 1. The total sample size of the statistical treatment is known as the *N* value in the number of replications to be taken for each day of operation, for each operator. As can be seen, this sample size value varies for each type of person, associating the behavior of the operating data for each of them with the associated dispersion measures. Finally, calculations of *Observed Time (O.T.)* and *Basic Time (B.T.)* are made, based on the following equations:

$$O.T. = \frac{\sum_{i=1}^{n} X_i}{n} \tag{2}$$

$$B.T. = [O.T.] * [Assessment\ Scale] \tag{3}$$

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The International Labour Organization (ILO) has determined a schedule with the main supplements for the workstation

The values for Equations 2 and 3 presented above allow the calculations to be identified that are associated with the processing times of each of the operators. The Observed time is known as "rigid" operating time, the characteristic of which does not take into account any factor or element pertaining to the design of the workstation or characteristics of the operator. In the case of Equation 3, the assessment scale for each of the workers is considered, according to their motor skills in performing the assigned functions.

2.5. Phase V: Study of time tolerances at the workstation: Supplements

Within the times and methods study, one of the main activities for the correct investigation of the workstation design involves breaking down the activities to be performed by each of the employees, in relation to the profile required within the company. When a process of immersion and study of the activities of the workstation is initiated, (Novillo, Álvarez & Zurita, n.d.) argue that three fundamental elements must be considered for correct performance at the workstation: education, the ability of the human body and training. And it is with regard to this last element that organizations nowadays seek to generate "real" production indicators in business decision-making. The International Labour Organization (ILO) has determined, according to previous studies, a schedule with the main supplements for the workstation, which are listed below (Estellés, Palmer, Albarracín & Romano, 2013).

Figure 8
Supplement matrix - International Labour Organization (ILO)

CONSTANT SUPPLEMENTS			
		Men	Women
1	**For personal needs**	**5**	**7**
2	**Fatigue-based**	**4**	**4**
VARIABLE SUPPLEMENTS			
		Men	Women
3	**Due to working in a standing position**	**2**	**4**
4	**Due to abnormal posture**		
	Slightly uncomfortable	0	1
	Uncomfortable (inclined)	2	3
	Very uncomfortable (lying down, stretched out)	7	7
5	**Use of force or muscular energy (lifting, pulling, pushing). Weight lifted in kilos**		
	2.5	0	1
	5	1	2
	7.5	2	3
	10	3	4
	12.5	4	6
	15	5	8
	17.5	7	10
	20	9	13
	22.5	11	16
	25	13	20
	30	17	max.
	35.5	22	
6	**Poor lighting**		
	Slightly below the calculated power	0	0
	Well below	2	2
	Absolutely insufficient	5	5
7	**Atmospheric conditions (variable heat and humidity)**	**0-10**	**0-10**
8	**Intense concentration**		
	Work with a certain degree of precision	0	0
	Precise or tiring work	2	2
	High-precision work	5	5
9	**Noise**		
	Continuous	0	0
	Intermittent and loud	2	2
	Intermittent and very loud	5	5
	Shrill and loud	5	5
10	**Mental stress**		
	Moderately complex process	1	1
	Complex process - attention divided among many projects	4	4
	Very complex process	8	8
11	**Monotony**		
	Slightly monotonous work	0	0
	Fairly monotonous work	1	1
	Very monotonous work	4	4
12	**Tedium**		
	Slightly boring work	0	0
	Boring work	2	2
	Very boring work	5	5

Source: Estellés et al., 2013.

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A performance measurement is generated for each employee

The supplements matrix shown in Figure 8 is divided into two main categories: The first refers to *constant supplements*, which are the time factors present at the workstation on a permanent basis: 1) *for personal needs*, in relation to the time that the employee requests to use the restroom, advice in relation to the execution of specific tasks or any situation other than the performance of the work activities; 2) *fatigue-based*, where the performance of work activities generates as a result both physical and mental exhaustion, which must be considered in the study tolerance.

A second category in the matrix is the *constant supplements*, which are characterized by being values present at the workstation, in which the proportions (%) assigned vary according to the type of work and the way in which it is performed. The categories within this type of supplements are: 3) working in a standing position, 4) abnormal posture, 5) use of force or muscular energy, 6) poor lighting, 7) atmospheric conditions, 8) intense concentration, 9) noise, 10) mental stress, 11) monotony, and 12) tedium. The factors of the previous supplements were analyzed and studied at each workstation, in the company of the production coordinator and in relation to the gender and population being studied. The results are shown in Figure 9.

The results shown in Figure 9 illustrate the results of the supplement studies for the activities investigated within the company. The determination of the constant supplements is made according to the gender of the worker (male/female); within the workstations, activities were identified where the tasks were performed in a standing position by the participants over a

Figure 9
Supplements matrix - Packaging Logistics Center (PLC)

		SUPPLEMENT(S) MATRIX													
		Constants		Variables											
Activity	Name	1	2	3	4	5	6	7	8	9	10	11	12	Total	Supplement (%)
Quality Inspection - piping	Distribution Op 1	7	4	4	2	0	0	0	0	0	1	0	2	20	1.2
Quality Inspection - piping	Distribution Op 2	7	4	4	2	0	0	0	0	0	1	0	2	20	1.2
Quality Inspection - piping	Distribution Op 3	5	4	2	3	0	0	0	0	0	1	0	2	17	1.17
Quality Inspection - piping	Distribution Op 4	5	4	2	3	0	0	0	0	0	1	0	2	17	1.17
Quality Inspection - piping	Distribution Op 5	5	4	2	3	0	0	0	0	0	1	0	2	17	1.17

		SUPPLEMENT(S) MATRIX													
		Constants		Variables											
Activity	Name	1	2	3	4	5	6	7	8	9	10	11	12	Total	Supplement (%)
Rack cylinder filling	Distribution Op 6	5	4	2	0	0	0	0	0	2	0	1	0	14	1.14
Rack cylinder filling	Distribution Op 7	5	4	2	0	0	0	0	0	2	0	1	0	14	1.14
Rack cylinder filling	Distribution Op 8	7	4	4	1	0	0	0	0	2	0	1	0	19	1.19
Rack cylinder filling	Distribution Op 9	7	4	4	1	0	0	0	0	2	0	1	0	19	1.19
Rack cylinder filling	Distribution Op 10	5	4	2	0	0	0	0	0	2	0	1	0	14	1.14

		SUPPLEMENT(S) MATRIX													
		Constants		Variables											
Activity	Name	1	2	3	4	5	6	7	8	9	10	11	12	Total	Supplement (%)
Mobile gas pumping	Distribution Op 11	7	4	4	0	4	0	0	0	0	0	1	2	22	1.22
Mobile gas pumping	Distribution Op 12	5	4	2	0	3	0	0	0	0	0	1	2	17	1.17
Mobile gas pumping	Distribution Op 13	5	4	2	0	3	0	0	0	0	0	1	2	17	1.17
Mobile gas pumping	Distribution Op 14	7	4	4	0	4	0	0	0	0	0	1	2	22	1.22
Mobile gas pumping	Distribution Op 15	5	4	2	0	3	0	0	0	0	0	1	2	17	1.17

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The current problem presented by the 'Packaging Logistics Center' (PLC) is the lack of a system for controlling, monitoring and standardizing of the processing times

considerable period of time, resulting in the values for each of the tasks presented. In the case of Factor 4, shortcomings were identified in the ergonomic designs of the workstation (chairs) for the quality inspection (piping) and rack cylinder filling activities. For Factor 10, the study was carried out and it was found that the inspection of gas cylinders requires a considerable degree of attention for its correct execution, specifically during the gas inspection activity. The characteristic of monotony of the work is present in the rack cylinder filling and mobile gas pumping tasks. Finally, and according to the study with personnel and operation coordination, the levels of motivation of those in charge were studied, with the results shown for Factor 12.

2.6. Phase VI: Matrix development in the times and methods study

In this research stage, the production standards corresponding to the operating times for each of the employees are analyzed and determined, including the supplements (%) in relation to the time tolerances within the work study. As a preliminary analysis, a detailed study of each of the activities performed at the workstation is carried out, using the engineering tool for the creation of detailed flow charts. The operational sequence, persons responsible, associated times and distances, wait times, storage, quality inspections and mobilized loads are described. Once the previous elements have been identified in each of the study times, the Standard Time (ST) (hours/unit) and Standard Units (SU) (units/hour) are calculated within the time matrix, based on the following equations:

$$S.T. = B.T. * [Supplement] \tag{4}$$

$$S.U. = [T.E.]^{-1} \tag{5}$$

Once the results are obtained from Equations 4 and 5, the performance indicators for each of the operators within each of the activities in this study are analyzed. A measurement of the performance values (number of units/month) produced by each of the employees is generated and compared to the results of the indicators established by the organization within the study. The results are shown in Figure 10.

The results shown in Figure 10 illustrate the standard operating time (ST) (worker performance) in relation to the time taken by the operator, according to the times study within the observations made. This type of indicator establishes the real operating time of the worker in the correct performance of the task, in each area of study: quality inspection, rack cylinder filling and mobile gas pumping. In addition, the organization's target indicator is illustrated, which relates the production indicators established by the organization, according to the methodology presented in Table 1, to the production ratio projected in an operating time of 24 days/month. When analyzing the performance of the *pipe quality inspection* activity, it can be seen that the organization's target indicator (720 units/month) is achieved by Operator 4 within this process, with a production performance of 768 units; Operators 1, 2, 3 and 5 fail to comply with this target, with production performance values of 576 units, respectively. Within the analysis carried out for the *rack cylinder filling* activity, there is evidence of a degree of compliance higher than that established by the organization's target goal by Operators 6, 7, 8, 9 and 10, with production values of 1052, 1066, 990, 974 and 1028 units/month, respectively. For this specific analysis case, and according to the results achieved, immersion and research with the employees is carried out to promote good manufacturing practices for the evolution of the performance of the operation being analyzed and the continuous

Figure 10
Standard Operating Time Results - Packaging Logistics Center (PLC)

improvement of the production standard for each of the processes analyzed. Finally, the analysis for the *mobile gas pumping* activity is presented, where it is shown that the goal was reached in 80% of the cases, the standard production values of which for Operators 11, 12, 13 and 15 were 960, 1152, 1152 and 1152 units/month, respectively; the non-compliance of one of the employees (worker 14) was evidenced, with a production performance of 768 units/month.

Different strategies are established to improve rates of work

2.7. Phase VII: Analysis of the results, generation of the production standards and presentation of the value proposal

Within the matrix analysis and the generation and development of the times and methods study, it is important to highlight the identification of needs and opportunities for each of the study activities. The analysis of the causes of non-productive factors within the organization is presented in the Pareto diagram in Figure 2. According to the above, it can be identified that 80% of the causes of non-productive times are due to machinery, transport and procedures failures, with values of 44%, 25% and 12%, respectively. In the solution and minimization of the results of the non-productive times identified, a list was made with the main proposals for improvement, according to the in situ surveying and the generation of solution proposals. The results are presented in Table 2.

Table 2
Solutions strategy matrix - Packaging Logistics Center (PLC)

Area	Cause - Pareto	Cumulative percentage	Causal description	Improvement strategy
Rack cylinder filling	Machinery failures	44%	The purge valves present deterioration, due to the lack of preventive maintenance plans, directly affecting the operating system and industrial process. This causes the operator to have to move to obtain a replacement valve, which affects the filling process and its continuity. (Average travel time per day: 6 minutes/day). The gas transfer connectors are deteriorated, due to the lack of quality and guarantees of the products offered by the suppliers. They must use temporary connectors and go to the warehouse to get them. (Average travel time per day: 3 minutes/day).	1. Change and replacement of rack equipment valves for cylinder filling, to optimize the process. 2. Change and replacement of product connectors for cylinder filling, to optimize the process.
Mobile gas pumping	Transport failures	69%	There are constant repetitive movements from the production area to the distribution area (Area 8). (Average travel time per day: 120 minutes/day/operator).	3. Ground pipeline direct supply system from the warehouse area (raw material) - production - distribution system.
Rack cylinder filling/ piping inspection/ mobile pumping	Procedure failures	81%	There are problems in determining standards to control the production of the organization's workforce. There is no systematic control of the production indicators for each of the operators. Bottlenecks are created within the production line.	4. Determination of production standards and calculation of ideal production levels, according to the times and movements study.

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According to the results obtained, various types of strategies are established that must be implemented within the organization to improve work rates and increase the productivity of the department, based on regular training, the study of procedures, standards, product analysis and the study of efficient work methods, among others. The above analysis is carried out for all the activities in the present investigation. The results are shown in Table 3.

Table 3
Matrix of standard production indicators - Packaging Logistics Center (PLC)

Activity	Operator	Activity performance (monthly)	Organization target (monthly)	Percentage of compliance	Ideal activity performance (monthly)	Compliance indicator (times study)
Quality Inspection - piping	Distribution Op 1	↓ 576	720	80%	614	NON-COMPLIANT
Quality Inspection - piping	Distribution Op 2	↓ 576	720	80%		NON-COMPLIANT
Quality Inspection - piping	Distribution Op 3	↓ 576	720	80%		NON-COMPLIANT
Quality Inspection - piping	Distribution Op 4	↑ 768	720	107%		COMPLIANT
Quality Inspection - piping	Distribution Op 5	↓ 576	720	80%		NON-COMPLIANT
Rack cylinder filling	Distribution Op 6	↑ 1,052	960	110%	1,022	COMPLIANT
Rack cylinder filling	Distribution Op 7	↑ 1,066	960	111%		COMPLIANT
Rack cylinder filling	Distribution Op 8	↓ 990	960	103%		NON-COMPLIANT
Rack cylinder filling	Distribution Op 9	↓ 974	960	101%		NON-COMPLIANT
Rack cylinder filling	Distribution Op 10	→ 1.028	960	107%		COMPLIANT
Mobile gas pumping	Distribution Op 11	↓ 960	960	100%	1,037	NON-COMPLIANT
Mobile gas pumping	Distribution Op 12	↑ 1,152	960	120%		COMPLIANT
Mobile gas pumping	Distribution Op 13	↑ 1,152	960	120%		COMPLIANT
Mobile gas pumping	Distribution Op 14	↓ 768	960	80%		NON-COMPLIANT
Mobile gas pumping	Distribution Op 15	↑ 1,152	960	120%		COMPLIANT

Table 3 shows the total results in relation to the production indicators for the Packaging Logistics Center (PLC). As can be seen in the quality inspection-piping area, there is a lack of compliance in relation to the ideal production performance by 80% of the workers. Activity performance indicators vary by 80% for operators 1, 2, 3 and 5, respectively. According to the above, the administrative department of the company has decided, in the present case, to continue working under the organizational production target indicator and to consider improvement strategies for the current process, in relation to the identified shortcomings: the correct identification of cylinders, valve revision system (identification of caps), safety labels and revision protocols are some examples of the training plans that the department operating personnel should receive.

Below are the monetary results in the cost/benefit ratio for each of the implementations (see Table 4). This session shows the results of the implementation of each of the improvement proposals in this research. In the case of Strategy 1, the change and replacement of valves on rack equipment for cylinder filling is established as an action plan. The commercialization and

Table 4
Cost/Benefit Ratio Matrix of the Improvement Proposals - Packaging Logistics Center (PLC)

Improvement strategy	Description of the element/process	Distribution operator	Wage/minute value	Business days worked	Average time savings/day	Profit per year	Total cost of the improvement
1	Rack cylinder filling	6	$78	288	6	$705,000	$874,000
1	Rack cylinder filling	7	$78	288	6		
1	Rack cylinder filling	8	$78	288	6		
1	Rack cylinder filling	9	$95	288	6		
1	Rack cylinder filling	10	$78	288	6		
	TOTAL	5	$82	288	6		
Improvement strategy	**Description of the element/process**	**Distribution operator**	**Wage/minute value**	**Business days worked**	**Average time savings/day**	**Profit per year**	**Total cost of the improvement**
2	Rack cylinder filling	6	$78	288	3	**$352,500**	**$770,000**
2	Rack cylinder filling	7	$78	288	3		
2	Rack cylinder filling	8	$78	288	3		
2	Rack cylinder filling	9	$95	288	3		
2	Rack cylinder filling	10	$78	288	3		
	TOTAL	5	$82	288	3		
Improvement strategy	**Description of the element/process**	**Distribution operator**	**Wage/minute value**	**Business days worked**	**Average time savings/day**	**Profit per year**	**Total cost of the improvement**
4	Quality Inspection - piping	1	$113	288	29	$3,335,000	$1,000,000
4	Quality Inspection - piping	2	$78	288	29		
4	Quality Inspection - piping	3	$95	288	29		
4	Quality Inspection - piping	4	$104	288	29		
4	Quality Inspection - piping	5	$ 109	288	29		
	TOTAL	4	$100	288	29		
Improvement strategy	**Description of the element/process**	**Distribution operator**	**Wage/minute value**	**Business days worked**	**Average time savings/day**	**Profit per year**	**Total cost of the improvement**
4	Rack cylinder filling	6	$117	288	20	**$1,120,000**	**$1,000,000**
4	Rack cylinder filling	7	$109	288	20		
4	Rack cylinder filling	8	$87	288	20		
4	Rack cylinder filling	9	$95	288	20		
4	Rack cylinder filling	10	$78	288	20		
	TOTAL	2	$97	288	20		
Improvement strategy	**Description of the element/process**	**Distribution operator**	**Wage/minute value**	**Business days worked**	**Average time savings/day**	**Profit per year**	**Total cost of the improvement**
4	Mobile gas pumping	11	$69	288	94	**$4,559,000**	**$1,000,000**
4	Mobile gas pumping	12	$74	288	94		
4	Mobile gas pumping	13	$78	288	94		
4	Mobile gas pumping	14	$104	288	94		
4	Mobile gas pumping	15	$95	288	94		
	TOTAL	2	$84	288	94		
					TOTAL	**$10,071,500**	**$4,664,000**

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There is a lack of compliance with the ideal production performance by 80% of the employees

determination of the total cost of the necessary inputs are carried out, with the generation of the budgetary report from three market suppliers and the selection of the appropriate commercial proposal in terms of quality specifications and cost for the needs of the rack cylinder filling activity ($874,000). This analysis is performed for each of the study scenarios and the calculation of the value proposal.

The results of the study show economic benefits of $705,000 and $352,500, in relation to the implementation of Strategies 1 and 2, respectively, generating investment costs of $874,000 and $ 770,000. The presentation of Strategy 4 generates economic benefits for the quality inspection, rack cylinder filling and mobile gas pumping activities of $3,335,000, $1,120,000 and $4,559,000, respectively, the investment values (implementation costs) of which are $1,000,000 for each of the three cases applied. This value is calculated for a projection of the professional staff responsible for the process of adaptation to the times and methods study within a 4-month period of training, coaching and implementation.

3. Conclusions

The methodological development of the times and methods study is an essential tool for determining real production indicators for organizational objectives and strategies. The adaptation and comparative analysis show a restructuring of the production indicators for the quality inspection area of 14.72%, rack cylinder filling of 6.46%, and the mobile gas pumping area of 8.02%. Each of the values above and their orientation in the adjustment and increase (in the case that the performance indicator is higher than the one established by the organization) or assessment and study (in the case that the performance indicator is lower than the one established by the organization) should be reviewed by the organization's strategic planning department, according to the parameters and resources present in the organization.

The design and study of the work allow us to identify the main elements that make up the productivity factors of each of the operators inside the workstation. Factors such as functions performed, ergonomics, related machinery and equipment and current work regulations directly influence the operational performance of the analyzed areas. The analysis of the workstation shows that the correct adaptation of the workstation, as in the case of the rack cylinder filling activity, for example, results in differences in production levels of approximately 10-15% between operators, in relation to finished products/month. Technical and technological characteristics within the processes must be guaranteed for the correct development and effectiveness of the task and their performance.

The divergence of the production values identified within each of the processes is caused by three main elements: the lack of updating and technological development, present in the absence of an industrial infrastructure (ground pipeline system) for the mobile gas pumping area; the lack of updating and availability of raw material in optimal conditions, as identified in the technical and physical failures present in the gas cylinders analyzed; and finally, the absence of a methodical structure for measuring and standardizing production indicators. In accordance with the above observations, improvement strategies have been established for each of the activities studied and the cost/benefit ratio of the present proposal has been quantified, with the total corresponding values of $4,644,000 and $10,071,500, respectively.

From the present research, it can be concluded that the learning curve of the operators increases over time, as the last study presented in the year 2018 shows an improvement in total operation times for the related activities of 143 minutes. This is a considerable reduction in

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The results achieved show economic benefits

order to boost productivity, control and improvement of the industrial processes, as well as the continuous improvement of the efficiency in the use of manpower.

The study of performance and measurement factors for the development of production levels and their standardization are not always the best option when the objective is to achieve the total optimization of the industrial system being studied. It is important to scientifically complement the research obtained by identifying the study variables and measuring their levels of dispersion. Events and metaheuristic causalities are essential for the planning, control and improvement of the company's production processes. Development methodologies, such as balancing of the production line through "Tabu searches," production scheduling with stochastic demand and sequence levels and the application of the ant colony algorithm in the resolution of the approach to storage, transport and distribution are some examples of solution methodologies currently demanded by the organization as alternatives in optimization and systematic programming.

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