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Application of lean manufacturing tools and ICT to increase productivity levels and reduce costs in the brewing industry in Ensenada, Baja California, Mexico

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ABSTRACT

This investigation was prepared to evaluate productivity levels because in 2018 there were low rates due to inadequate planning in the manufacturing stages of a brewing industry, located in the city of Ensenada, Baja California, Mexico. Starting in 2019 and 2020, even with the presence of Covid19, productivity rates increased. Said increase in productivity was due to the application of lean manufacturing tools, such as the Value Flow Map (MFV), Kanban and Kaizen, managing to generate an efficient fluid process, and thereby increasing levels of competitiveness. In addition, an automated system was used using Information and Communication Technology (ICT) to control time and improve the flow of the production process. With the analysis of the aforementioned tools, the stages of the production lines with the highest incidence of causes that caused, in certain manufacturing stages, poor productive performance of personnel and machinery were determined, indicating levels less than 50% and thus costs of production increased, generating great concern in the directive, managerial and supervisory personnel. In addition to the lean manufacturing analysis, an automated system was designed and applied, controlled by ICT, to help detect when the process flow was not optimal, indicating the moments in which the machines performed technical stoppages and stopped the production line. The investigation was carried out in 2020, even with the presence of Covid19, the industry where the analysis was carried out continued operating normally with the safety and hygiene protocols.

Keywords Lean Manufacturing, Productivity, Competitiveness, Brewing Industry, Costs

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INTRODUCTION

The beer industry is one of the most important in the global economy, which generates a relevant percentage of the Gross Domestic Product (GDP) of the countries that are dedicated to this type of industry. In this research, an analysis was made of the presence of low productivity and quality indices and a large number of defects in manufactured products (Arrieta J et al., 2011). These products had the following defects: (1) spilled liquid level (beer) product loss and economic losses, (2) low liquid level (beer) and (3) bottles without a label. These three defects required work as overtime, and therefore the generation of extra costs. Based on this, continuous improvement activities were developed, with lean manufacturing tools: Kaizen, Kanban and Value Flow Map, in conjunction with the use of ICT coupled to an automated electronic system (García J, 2018).

Lean Manufacturing Tools

Lean manufacturing is widely applied in industrial processes of any type of industry, and in this research carried out in a brewing industry, three lean manufacturing tools were used, such as the Value Flow Map, Kanban and Kaizen. Each of the tools used in this scientific study is explained below (Fontalvo T,, 2018).

a) Value Flow Map. It is based on a process of verification of industrial operations, where the activities of the value chain are evaluated, being a management tool that helps to quickly detect variation that causes a problematic situation and with-it defective products.

b) Kanban. This tool had its origin in the Toyota company installed in Japan in the 1930s, when it was developed for the analysis of industrial processes in automotive manufacturing. This tool is used as a visual method to control the activities of industrial operations, whether manual or automated, in order to establish an organization in an optimal way, with the aim of increasing productivity and quality levels and increasing the quantity of products. manufactured, in addition to reducing defects and errors .

c) Kaizen. It is based on the development process of the Deming circle, to make the required improvements in industrial operations with the modification or development of new methods, mechanisms or annual and automated systems, or the use of new equipment and industrial machinery, to achieve the goals of increases in quality and productivity, as well as manufacturing the quantity of products required for the customer and reducing or eliminating defects and errors.

The use of the value stream map has the function of showing the various stages of the industrial process, to identify each characteristic that generates an action in each industrial activity. Each characteristic detected in each stage of the industrial process, contributes a value that is relevant when carrying out continuous improvement, and is represented in the value flow map, to determine the priorities to be evaluated immediately. Figure 1 shows an illustration of a value stream map (Gutiérrez H et al, 2013).

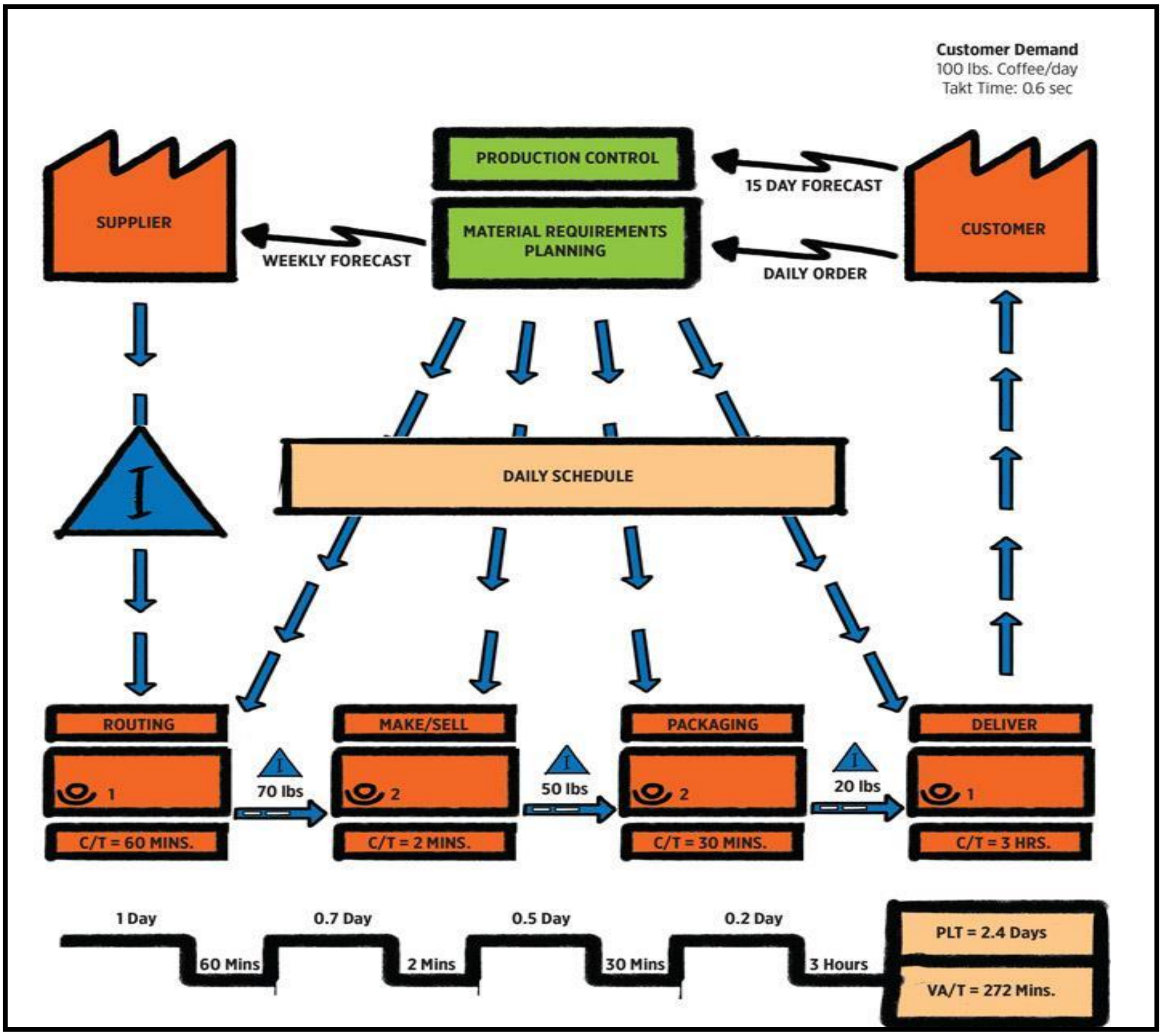

Figure 1 Representation of the Value Stream Map for the development of continuous improvement.

Source. https://www.reliableplant.com/value-stream-mapping-31747

The Kanban tool is used in conjunction with the Kaizen tool with which industrial operations are evaluated and the pertinent improvements are made with the actions of planning, preparing, verifying and acting (PEVA Model), meaning the way to act at the required moments that support in the solution of problems and thus not generate problematic situations in the field of decrease in productivity, quality and quantity of products that so much worries directive, managerial and supervisory personnel (Gómez R, 2012).

The way to start the activity of analyzing with the Kanban tool is to observe in detail the flow of industrial operations, managing to obtain with certainty a visualization of the functions of each person, as well as the equipment, machinery and industrial systems that perform the tasks. industrial operations. Subsequently, the actions of both people and those of the equipment, machinery and industrial systems are delimited, analyzing the times and movements of each activity, to determine if it is necessary to carry out some type of improvement, which helps to increase productivity levels, quality and quantity of manufactured products. And once the previous stage has been elaborated, the productivity and quality criteria of each manufactured product are analyzed, to adequately develop the required improvements and the improvements are developed, constantly evaluating them during a certain period of time, to verify that their functionality is optimal and not may present a problematic situation (Herrera R, et al., 2011).

Once the improvements have been developed, the changes that allow visualizing the increases in the induces of productivity, quality and quantity of manufactured products can be observed, in addition to avoiding an accident or work-related illness. In order to implement the improvements with the Kaizen tool, specific and real goals must be established for each stage of the industry process, thoroughly analyzing each activity and developing an optimization plan that generates benefits quickly. One might think that once the improvements are made in each stage of the industrial process, the solutions will be obtained immediately, but sometimes an improvement must be evaluated for a certain amount of time until it stabilizes and thus the benefits of its application are reflected. . Figure 2 shows the information of the Kanban and Kaizen tools (Fortuny J et al., 2008).

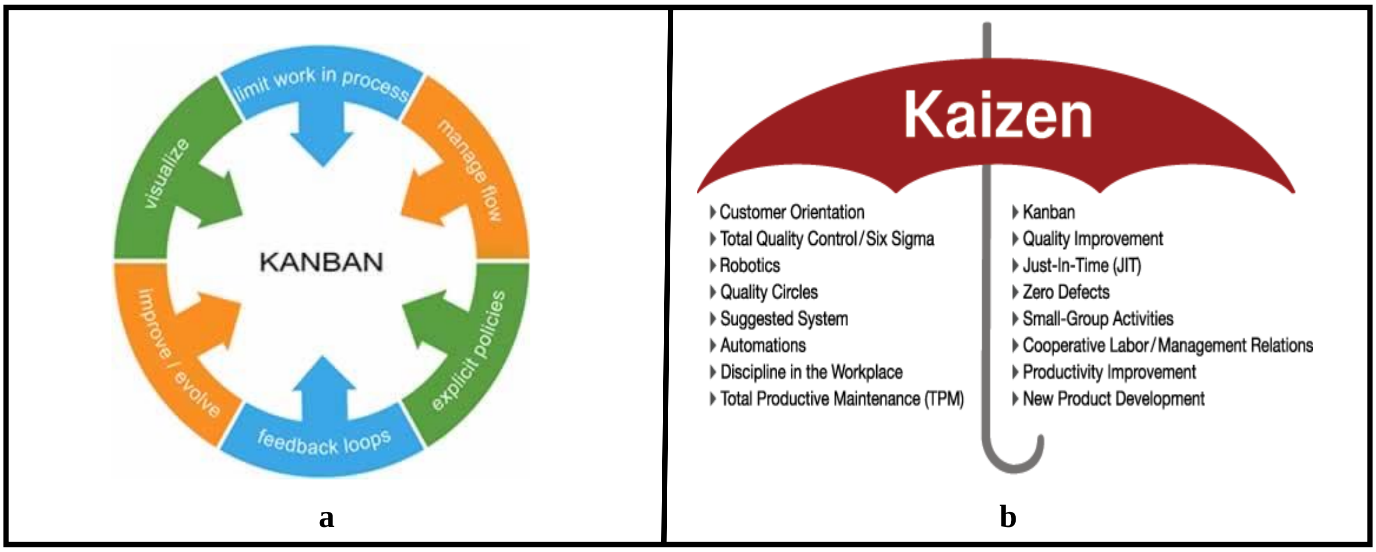

Figure 2 Representations of Kanban and Kaizen for the development of continuous improvement.
Source (a). https://www.accuratereviews.com/kanban-meaning-and-how-it-works/
Source (b). https://www.kanbanchi.com/what-is-kaizen

Beer Industry

It is a relevant type of industry in the countries where it is developed, being an important factor in the Gross Domestic Product (GDP), due to its large amount of demand for manufactured products and the enormous generation of sales, as it is a product consumed by various social classes. In the Republic of Mexico there are two main global brand companies, being Grupo Modelo and Grupo Heineken Mexico (previously called Cervecería Cuauhtémoc Moctezuma), and others on a smaller scale with respect to the number of products manufactured and sales (ACERMEX, 2019). In addition, Craft beer production companies are included, such as the company, where this research was carried out, which is located in the city of Ensenada, Baja California, in the northwest of the Mexican Republic. Figure 3 shows an industrial process of brewing beer.

Figure 3 Industrial process of a brewing company similar to that of the industry where the research was made

Source. https://www.puntoporpunto.com/secciones/punto-de-encuentro/cerveceras-en-mexico-continuan-en-la-incertidumbre/

Productivity and Costs

It is an important factor of the industries that has a great relationship between these terms and with the production processes where economic gains or losses can be determined. Productivity is considered an economic measurement action, managing to calculate goods (products manufactured in industrial companies) and services (activities that are offered by companies that provide services to consumers). Figure 4 represents the balance factor of costs and benefits in industrial companies, where productivity and costs are involved for a better understanding of this relevant relationship (Marin J et al, 2009).

Figure 4 Balance of costs and benefits associating productivity and quality in industries

Source. https://www.123rf.com/photo_23393212_reduce-costs-by-increasing-quality-productivity-and-speed.html

In productivity, certain aspects are determined such as the number of workers and their skills and aptitudes, as well as investment capital, production times, distribution and delivery to customers. Productivity is associated with the quality factor, which in turn is related to manufacturing costs and is a relevant aspect in the growth or decline of industries. The link between productivity and quality is essential and is focused on the application of a very strict discipline so as not to generate economic losses, which is associated with cost analysis.

Information and communication technologies

This type of technology is based on applying the resources and tools necessary for the development of computer programs (software) in various activities where industrial processes are contemplated, where there are countless applications (Valderrama A et al., 2011). The development of these programs is based on the requirements specified in the characteristics of the different types of industrial processes, using a computerized system for the activities of analysis, verification, administration, control, organization and distribution essentially; developed with technological systems such as computers (computerized systems), telephones and televisions, mainly (Boyd D et al. 2012). These computerized equipments are interconnected with networks (wired or wireless system), forming together the so-called Information and Communication Technologies (ICT). Figure 5 shows how ICT interacts with industrial processes in various types of industries.

Figure 5 Uses of ICT in industrial processes
Source. https://www.unir.net/ingenieria/revista/el-impacto-de-la-industria-4-0-en-la-logistica-6-avances-que-ya-revolucionan-el-sector/

Automated control systems

They are widely used in the industry to control the activities of industrial processes, helping to a great extent to detect weaknesses and strengths at each stage of the process to increase productivity and quality levels, based on the reinforcement of automated systems controlled by computerized teams that train ICT. These automated control systems include cybernetic, electronic, electromechanical and electropneumatic devices widely used in industrial processes in any industry (Loza A et al., 2009). Figure 6 illustrates an automated system used in an industrial process in a brewing industry.

Figure 6 Automated industrial process in the brewing industry using ICT.
Source. https://www.eurobots.net/news/la-industria-cervecera-y-el-impacto-de-los-robots-industriales/

MATERIALS AND METHODS

In this investigation, an experimental process was carried out that included analysis in an industrial process of a brewing industry, considering the following evaluations:

a) Characterization of the industrial process using manufacturing tools such as the Value Stream Map, Kanban and Kaizen.

b) Analysis of productivity, quality and costs.

c) Development of a prototype of an automated electronic system controlled by a computerized equipment using ICT.

Measuring equipment such as the Besonere brand digital chronometer were used to evaluate the manufacturing times of each stage of the industrial process, made by both the personnel who operate the equipment, machinery and industrial systems, as well as a voltage, electric current and power meter. electrical such as the GEN brand voltage, current and power factor tester; to determine the types of electronic devices used in the prototype coupled to a computerized system.

RESULT AND DISCUSSION

The investigation generated relevant information from the evaluations made to determine the types of improvements to be made in the industrial process of the brewing industry where the scientific study was prepared and shown in the following sections.

Characterization analysis

It was developed to detect the weaknesses and strengths of each stage of the industrial process (being seven stages) and explained in the analysis of the value stream map. For the beginning of the research, the analysis of the value flow map was carried out as the first activity, to know the operations of the industrial process in the brewing industry where the scientific study was carried out and thus determine its value as part of the manufacturing process. Table 1 shows the activities of the industrial process and their level of relevance.

Table 1 Analysis of the process flow distribution with the value flow map

Step	Description of the step	NCP	Improvement developed
1	Verification of the bottle in good condition made up of two activities: (a) visual inspection by a person from the operating area and (b) inspection by means of an optical sensor operated by an automated system	4	In this stage, an improvement was made to verify and control and thus achieve an optimal operation of the automated system through ICT, obtaining information instantly on this operation and quickly making the necessary adjustments
2	Placing the bottle in an area to start the filling activity manually by an operative person from the manufacturing area	3	There was no need for a momentary upgrade. In the future it could be applied.
3	Brewing processes with an automated system	5	At this stage, an improvement was developed to verify and control and thus achieve optimal operation of the automated system through ICT, to obtain information instantly on this operation and quickly develop the necessary adjustments
4	Activity of filling beer in the bottles in good condition by means of an automated system	5	En esta etapa se desarrolló una mejora para verificar y controlar y así lograr un óptimo funcionamiento del sistema automatizado por medio de las TIC, para obtener información al instante de esta operación y desarrollando rápidamente los ajustes necesarios

5	Full bottle inspection operation, verifying the filling level of the beer in the bottle by means of visual inspection manually by an operative person from the manufacturing area, manually by an operative person from the manufacturing area, and by a system automated	5	At this stage, an improvement was made for verification and control and thereby achieve optimal operation of the automated system through IT, obtaining information on this operation instantly and immediately making the required adjustments.
6	Activity of gluing the label on the bottle with product made by an automated system	4	At this stage, an improvement was developed for the verification and control and thereby achieves an optimal operation of the automated system by means of a computerized equipment using a computer program using ICT and quickly making the necessary adjustments.
7	Manual packaging operation and warehouse organization with operating personnel from the manufacturing area	3	In this stage, the Kanban and Kaizen tool was applied for an optimal organization of the products produced and placed in a warehouse.

LCP-Level of complexity in the process expressed from 1 to 5, where the higher the level, the higher the degree of complexity.

The table above shows the stages of the brewing process in the industry where the scientific study was carried out, indicating the explanation of each stage, the level of complexity of the operation and the improvement made in each industrial operation, except in one where At the moment it is not necessary to carry it out and consider it as an improvement in the near future and part of this research that is still ongoing. It is observed in the information in the table that the levels of complexity range from level 3 to 5 in various stages. Figure 7 represents a flow diagram of the industrial operations as explained in table 1, of the brewing company where the research was carried out.

Figure 7 Representation of the process flow distribution

Subsequently, a format was developed to apply the Kanban tool, shown in table 2, of the monitoring of the flow of the material, by-product and final product.

Table 2 Process flow evaluation format with Kanban and Kaizen tools

Verification	1	2	3	4	5	6	7	8
Step								
1								
2								
3								
4								
5								
6								
7								

A. Indicates that the material, by-product or final product is within the quality parameters

B. Indicates that the material, by-product or final product is not in the quality parameters

Based on the developed format (which was not available in the industrial process) and which was used for the verifications in the industrial process during each hour in eight-hour shifts from Monday to Friday, an evaluation was carried out in hourly, daily, weekly periods, monthly and seasonal of the year 2020 shown in table 3.

Table 3 Process flow analysis with Kanban and Kaizen tools (2020)

Monthly Period	1	2	3	4	5	6	7	8	9	10	11	12
Step												
1	A	A	A	A	A	A	A	A	A	A	A	A
2	B	A	A	A	A	A	A	A	A	A	A	A
3	B	B	A	A	A	A	A	A	A	A	A	A
4	B	B	A	A	A	A	A	A	A	A	A	A
5	B	A	A	A	A	A	A	A	A	A	A	A
6	B	B	A	A	A	A	A	A	A	A	A	A
7	B	B	A	A	A	A	A	A	A	A	A	A

A. Indicates that the material, by-product or final product is within the quality parameters
B. Indicates that the material, by-product or final product is not in the quality parameters

As can be seen in table 3, at the beginning of the investigation there was no control of the flow of the material, by-product and final product; Therefore, improvements (Kaizen application) were made to organize these and place locations for each one, which the industrial process did not have. It is shown that from the third this aspect was controlled and with it both the levels of productivity and quality, as well as the quantity of manufactured products increased, reducing operating and manufacturing costs and increasing sales and economic profits. The numbers in the upper part indicate the S's of the year, the month of January being the 1st and so on until the month of December represented by the number 12.

Evaluation of productivity, quality and costs

An analysis of the parameters of productivity, quality and costs (represented by economics data) was carried out; indicating their relationship in table 4.

Table 4 Productivity, quality and cost analysis (2020)

Monthly Period	1	2	3	4	5	6	7	8	9	10	11	12
Step												
1	1,3,5	2,3,5	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6
2	1,3,5	2,3,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6
3	1,3,5	1,3,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6
4	1,3,5	2,4,5	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6
5	1,3,5	1,3,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6
6	1,3,5	2,4,5	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6
7	1,3,5	2,3,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6	2,4,6

PLL (1). Productivity-Low Level, PHL (2). Productivity-High Level
CNB (3). Productivity-Low Level, CNA (4). Productivity-High Level
ENB (5). Productivity-Low Level, ENA (6). Productivity-High Level

PNB (1). Productividad-Nivel Bajo, PNA (2). Productividad-Nivel Alto
CNB (3). Productividad-Nivel Bajo, CNA (4). Productividad-Nivel Alto
ENB (5). Productividad-Nivel Bajo, ENA (6). Productividad-Nivel Alto

Table 4 illustrates the levels of productivity, quality and costs (represented by economic data), indicating that at the beginning of the investigation, the levels of the parameters mentioned, where it is observed that in the first two months of the scientific study, no they reached the goals of productivity and quality, and with it the quantity of elaborated products, originating high operating costs and low sales and the presence of economic losses. But it was possible to stabilize the aforementioned parameters, starting in the third month and thus obtain high rates of productivity, quality and quantity of manufactured products and generate low operating costs, increased sales and economic profits.

Automated device development

An analysis was carried out to organize the products made in the warehouse with an automated system that generated an indicator signal when a product was not in its corresponding place to achieve optimal organization. The prototype proposed as an automated detection device is represented in the form of a block diagram in Figure 8.

Figure 8 Representation of the stages of the automated device

The system contemplates the stages represented in figure 8, with each stage of the automated system being explained immediately:

A) Power supply. It generates the electrical energy necessary for the automated system to operate in optimal conditions.

B) Product detection module in correct location using barcode. It is a system that contains a bar detector module, a component made up of a black space and a blank one that together read the codes and the component that generates the bar code characters.

C) Indicating device. It is an element that originates an indicator signal, being in this automated system it is a low intensity light source.

D) Peer to Peer system. Components that generate data information by means of a signal captured from the bar code and be sent to a single computerized computer that stores the captured data

E) Information storage equipment. Computerized computer that stores the data captured with the barcode system.

CONCLUSION

The research carried out in a brewing industry located in the northwest of the Mexican Republic helped to generate the necessary improvements that will generate the control of the industrial operations of the manufacturing area. The detailed analysis with the manufacturing tools originated the information required to determine what was happening in the industrial process and thus make the pertinent improvements. The development of the automated system supported to a great extent to control the location of the products in the warehouse area and not to generate confusion when sending to the clients and to avoid claims.

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