UNIVERSIDAD RICARDO PALMA

ENGINEERING FACULTY

PROFESSIONAL SCHOOL OF INDUSTRIAL ENGINEERING

INDUSTRIAL AUTOMATION

RESEARCH WORK

"Bottle size sorting machine"

INTEGRANTS:

- **Alcantara Villalobos, Alejandra**
- **Ayala Mendoza, Carlos Javier**
- **Becerra Rodríguez, Martha Sofia**
- **Chirinos Mejia ,David**
- **Cisneros Gomez, Nadinne Erika**
- **Delgado Quispe, Luis Enrique**
- **Muñoz Gonzalez, Richard**
- **Olivera Cruzado, Gerardo**
- **Ramos Ccala. Lucero de los Angeles**

Professor: Dr. José Antonio Velásquez Costa

Lima - Peru

2022 - I

SUMMARY

This research has been developed at the Faculty of Engineering of the Ricardo Palma University, considering our objective to automate the process of classifying bottles according to their size. Formerly many companies worked manually the process of classification of bottles, however with the advancement of technology this has been able to change that is why we decided to make a bottle sorting machine according to the size of each one; another objective of the project is to reduce time in the classification of bottles and thus be able to increase the productivity of the process.

Currently in Peru there are a few companies that are automated which is a problem because it generates a delay in daily production and productivity, although it is true that the automation of a company is not cheap in the long term investment is justified because by reducing labor and margin of human error will avoid personnel costs. The objective of this work is to study and analyze the transport of material by a conveyor belt, analyzing the margin of error, costs and productivity of the machine, as well as to propose and motivate future companies to implement this machine.

Key words: actuators, bottle, controller, design, classify.

ABSTRACT

This research has been developed in the Faculty of Engineering of the Ricardo Palma University, considering our objective to automate the process of classifying bottles according to their size. In the past, many companies worked the bottle classification process manually, however with the advancement of technology this has been able to change, which is why we decided to make a bottle classification machine according to the size of each one; Another objectives of the project is to reduce times in the classification of bottles and in this way it would be possible to increase the productivity of the process.

Currently in Peru there are a few companies that are automated, which is a problem since it generates a delay in daily production and productivity, although it is true that the automation of a company is not cheap in the long term, the investment is already justified. that by reducing labor and the margin of human error, personnel costs will be avoided. The objective of the work is to study and analyze the transport of material by a conveyor belt, analyzing the margin of error, the costs and the productivity of the machine, as well as proposing and motivating future companies to implement said machine.

Keywords: actuators, bottle, controller, design, classify.

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INTRODUCTION

Plastic is one of the most widely accepted resources and also with a great demand in the Peruvian industry since it is widely used in the elaboration of different containers such as soft drinks, mineral waters, etc. Containers made from this element need to be classified differently from the others.

Due to this factor, a bottle size sorting machine has been designed, which will be able to help with this process. This machine will be developed for the improvement of the processes and to be able to have a better classification.

Science has updated technology over time, so as technology advances, companies are updated and automation will be observed over time.

The bottling industry is one of the areas where there is more environmental pollution, being Latin America one of the main consumers of plastic bottles, so their collection and recycling should be an area of business opportunity as well as a way to help the environment.

In Peru there is an opportunity in bottle recycling, so a machine that separates plastic bottles could help optimize the bottle separation process.

CHAPTER 1: THEORETICAL FRAMEWORK

1.1. Theoretical basis

1.1.1. Automation

As pointed out by Carrillo, V. (2008) "Automation is the reduction of labor, and use the necessary resources without wasting them. And the application of mechanical and electronic systems and computational bases to operate and control production."

Automation is defined as:

"an engineering discipline that makes up the industrial instrumentation and includes sensors, sensors, field level transmitters, control systems, monitoring and management, all in real time to control and monitor operations in plants, this is done through the following techniques: design, simulation and manufacturing" (Mandado, 2009).

For Núñez (2017) automation:

"It is the action of replacing the human operator by mechanical or electronic devices in an industrial process, so that tasks that were dangerous, tedious or that were limited by human capacity can be elaborated even more efficiently by automation, without causing risks to the operator and allowing him to devote his capabilities to other tasks of less danger and greater intellectual contribution, in which his intervention today is essential" (Núñez, 2017).

In industrial automation there are three classes, which are:

a. Fixed automation: this kind of automation is applied when the production quantity is very high, which will allow to know the cost of manufacturing the equipment to be used to separate our selected product with a good productivity.

b. Programmable automation: it will be used when the production has a low yield and there may be different products. This design will allow to be able to adapt to different changes in the configuration.

c. Flexible automation: it is used when the production has a medium performance, it has the characteristics of the two types of automation mentioned above. It can be controlled by several computers.

García, E. (2002) points out about the concept of automation that:

"It is associated with the elimination or reduction of human participation in the different productive processes, taking into account the application of mechanical, electronic and computerized systems, in order to operate and control production with greater efficiency and effectiveness. Additionally, this concept means the integration, for strategic purposes, of a wide range of advanced information and state-of-the-art engineering discoveries in production processes" (García, E. 2002).

In this sense, automation is composed of an operational part in charge of the execution of the different activities that are part of a process through the different elements that make it up; and a control part that is in charge of coordinating the activities of the process among which are quality control, tool management and supervision operations".

The following is a schematic of an automated system taking into account the parts that make it up:

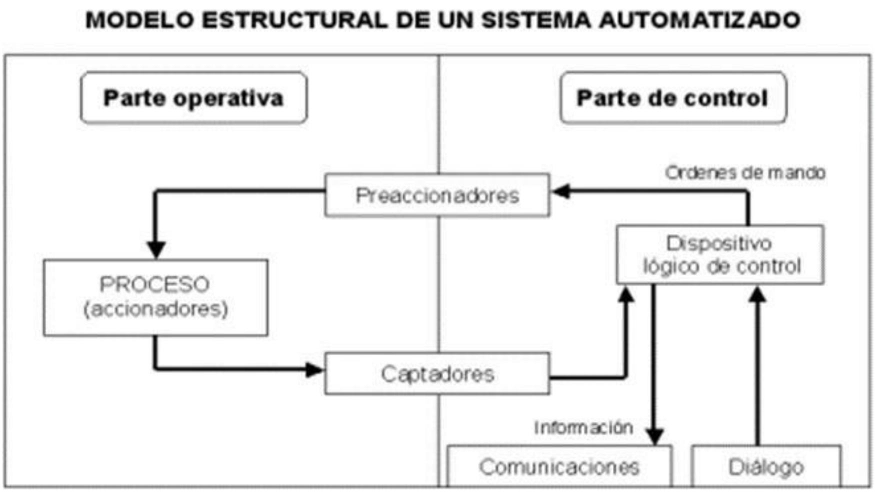


Figure 1: Structural model of an automated system

SOURCE: GARCÍA, Emilio. Automation of industrial processes. Mexico, Alfaomega Grupo Editor, 2002.p. 11.

For Zambrano (2006) the pre-actuators are:

"Elements that are used to activate the actuator which allows to execute movements within a system and can be pneumatic, hydraulic or electric. For its part, the sensors are those elements that receive the signal to send it to the control device. Automatic control is "the maintenance of the value of a certain condition through its measurement, determination of the deviation in relation to the desired value, and the use of the deviation in order to generate and apply a control action capable of reducing or canceling the deviation, over the years the industrial sector has been globalizing and has been very necessary to use new technologies, industrial automation and industry 4.0 currently serve as a means of global expansion for companies and / or factories; for example, one can know what is happening in the plant of another country, without leaving the base plant. As well, these technological advances are used for means of transportation, communication methods, facilities, etc. Having this new industry has benefited many and has made everything simpler. According to the level or automated system control can be pneumatic or electronic type and according to its application this can be with fixed value (constant) or with variable value (changing over time)". (Zambrano, 2006)

Depending on the needs of the company and the economic aspect related to the estimated investment for a given project, there are different levels of automation shown in the following graph:

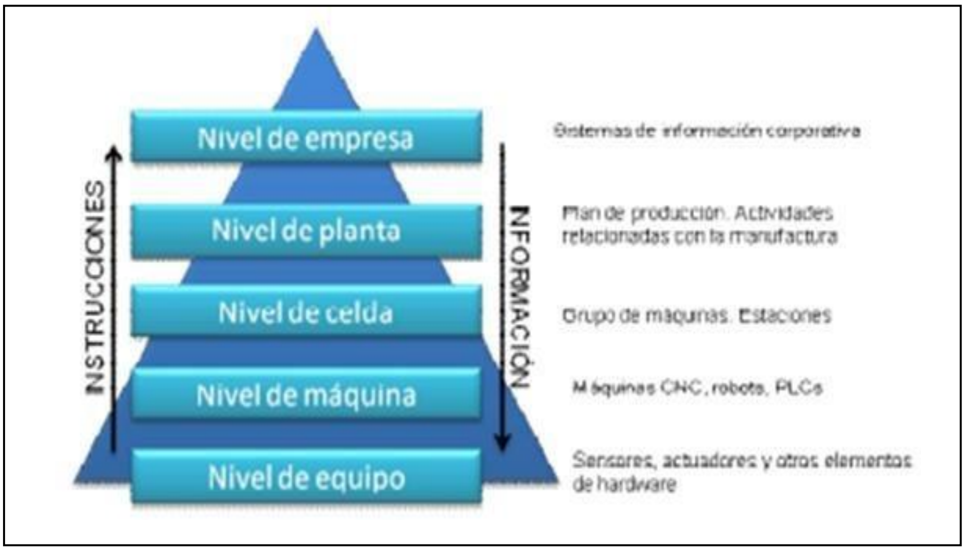


Figure 2: Levels of automation

SOURCE: Introduction to Industrial Automation. Gabriel Zambrano. July 2006.

Automation objectives

• Competitiveness: reducing production costs, improving production quality and increasing the number of items produced per hour.

• Safety: avoidance of human labor in order to facilitate and improve working conditions...

• Quality: provide added value compared to the competition.

• Avoiding human limitations: performs task where humans have difficulties and/or requires greater precision

• Product availability: optimize operations so that the product is always in circulation and there are no shortages in the market.

-Tooling flexibility: simple and quick production line changeover for the manufacture of other products

1.1.2. Sorting Machine

Companies use sorting machines in a process of improving the productivity of the sorting operation, in this case the size sorting machines will help to improve the accuracy at the time of selecting the product, the bottles.

Figure 3: Sorting machine

Author: Directindustry

Nowadays, bottle sorters play a very important role in the bottling plant. Their job is really simple, that of sorting bottles depending on whether they comply with certain specific values.

The bottles are subjected to an exhaustive, high-precision analysis in the different routes of the filling groups, which has a minimum margin of error and a high level of stringency. Depending on the filling line, different control points can be found, which have their own criteria.

Main function of the classifiers:

It is known that there are all kinds of bottles with a certain value either for height, shape, color, level, etc. The sorters play an important role as they help to analyze each of the bottles and process them in real time according to the values established in question, being able to differentiate between several types of bottles and specifications at the same time.

Types of bottle sorters:

There are two types of bottle sorters:

- The qualifiers, which have the function of differentiating between the different types of bottles and thus being able to classify them for use.
- In-line inspectors, this type of sorting machine classifies bottles depending on whether they are suitable for use or not.

1.2. Objectives

1.2.1 General Objective

To be able to mechanize the development of the separation of bottles according to their size.

1.2.2 Specific Objectives

- Reduce time in sorting bottles by size.
- To increase the productivity of the process of bottles sorted by size.

CHAPTER 2: DESCRIPTION OF THE CURRENT PROCESS

2.1. Description of the process

The current process is based on the classification of bottles by size, this process begins at the reception of these containers. After having all the bottles, they are placed by the workers on the conveyor belt, passing through the first visual check by the workers in charge, who are in charge of making sure that there are no foreign objects in the bottles; approximately 10 people are used for this check.

At the second station of the conveyor belt there are 6 more people in charge of sorting the small, medium and large bottles. After being sorted, the workers place them in the corresponding boxes.

Figure 4: Bottle transfer

Author: Inmagine Lab

2.2. Flow diagrams

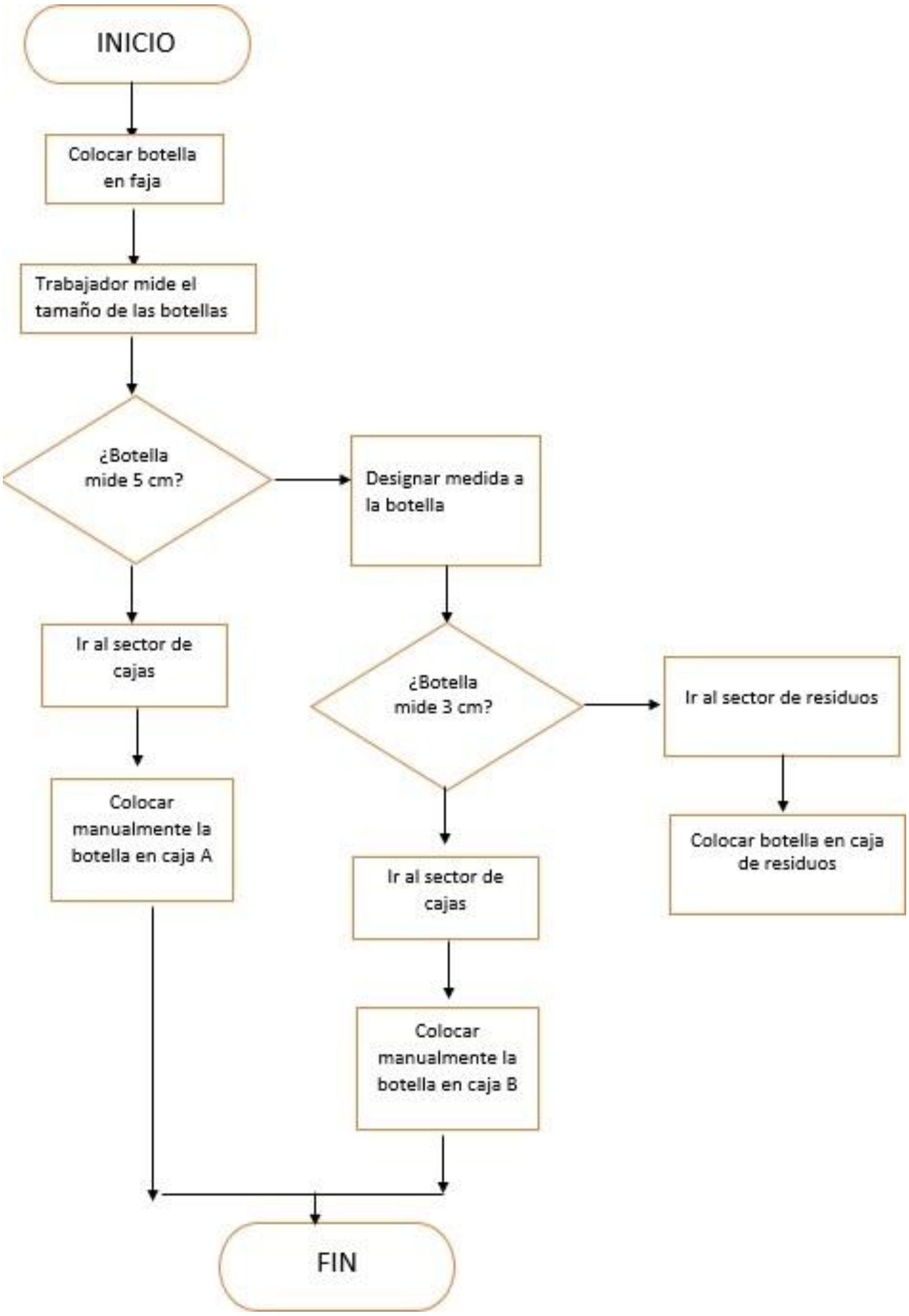
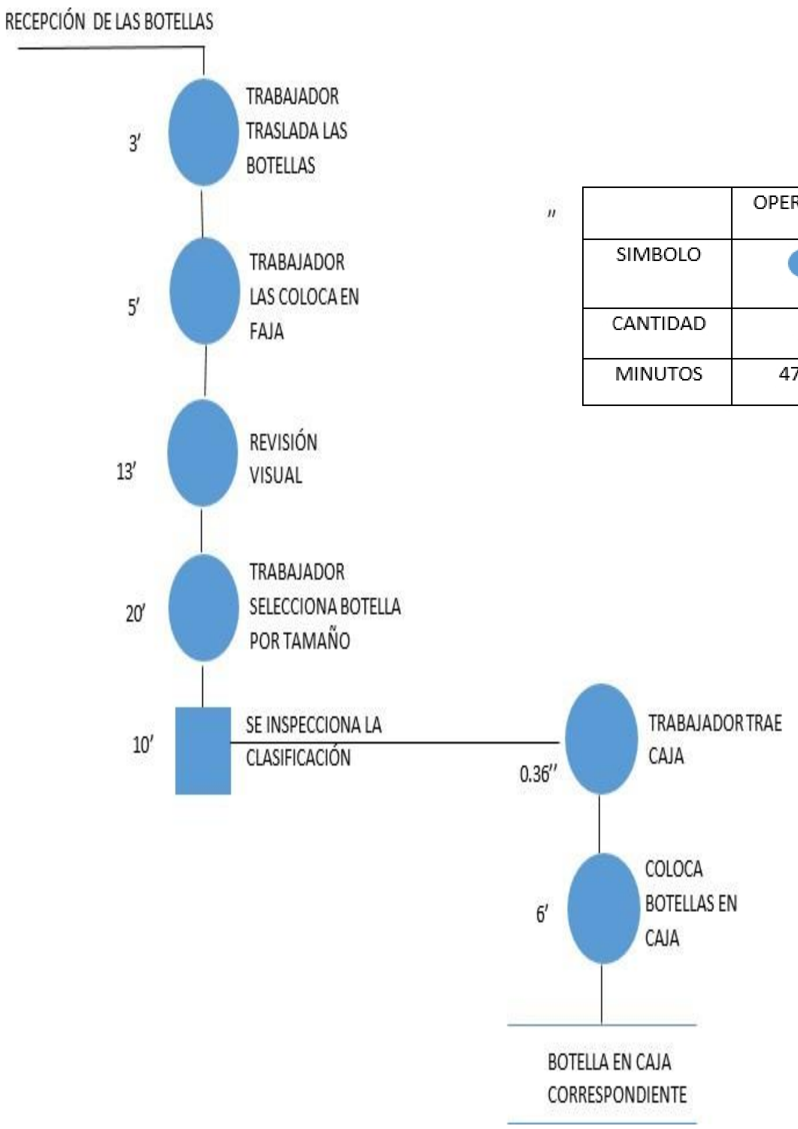


Figure 5: Flow diagram of the current process

Author: Own elaboration

2.3. Operations Diagram



	OPERACIÓN	INSPECCION
SIMBOLO	●	■
CANTIDAD	6	1
MINUTOS	47.36′	10′

Figure 6: Diagram of operations Author:

Own elaboration

2.4. Analysis diagram

DAP								
Ubicación	Universidad Ricardo Palma		Autor		Grupo	1		
Actividad	Diagrama de actividades		Revisado por					
Fecha	28/04/2022		Revisado por P.C.P					
Operador	Estudiantes de ingeneria industrial		Aprobado por					
N	DESCRIPCIÓN	T (min)	SIMBOLO O	⇨	D	□	▽	Distancia
1	Ingreso de botellas	3	x					
2	Trabajador traslada las botellas	5		x				0.1 m
3	Trabajador las coloca en faja	13	x					
4	Revision visual	20				x		
5	Trabajador selecciona las botellas por tamaño	20	x					
6	Trabajador trae caja	0.38		x				0.1 m
7	Trabajador coloca botellas en caja	6	x					
Total		67.38						

Figure 7: Process analysis diagram Author:

Prepared by the authors.

2.5. Automation plan Gantt

GANTT DEL PLAN DE AUTOMATIZACIÓN

NOMBRE DEL PROYECTO:MÁQUINA SELECCIONADORA DE BOTELLAS POR TAMAÑO

INICIO:01/04/2022

FIN:30/06/2022

PLAN DE AUTOMATIZACIÓN	ABRIL				MAYO				JUNIO			
	1	2	3	4	5	6	7	8	9	10	11	12
DEFINICIÓN DEL PROYECTO	■											
BÚQUEDA DE INFORMACIÓN		■										
PROPONER SOLUCIONES AL PROBLEMA		■										
REDACCIÓN DEL PROYECTO(INFORME)			■									
COTIZACIÓN DE MATERIALES				■								
COMPRA DE MATERIALES				■	■							
DISEÑO DEL PROYECTO					■	■	■					
ENSAMBLE DEL PROYECTO							■	■	■			
CABLEADO DEL PROYECTO								■	■			
PROGRAMACION DEL PROYECTO									■	■	■	
PRUEBA DEL PROYECTO											■	■

Figure 8: Gantt of the automation plan Author:

Own elaboration

*Gantt of automated machine set-up

Nombre del proyecto MÁQUINA SELECCIONADORA DE BOTELLAS POR TAMAÑO

Fecha de Inicio 18/04/2022

Día Corriente 18/04/2022

#	PASOS DE LA MÁQUINA AUTONATIZA	INICIO	FIN
1	PRESUPUESTROS DE PIEZAS	18/04/2022	18/04/2022
2	RECOLECCION DEL DINERO	18/04/2022	18/04/2022
3	COMPRA DE PIEZAS	19/04/2022	20/04/2022
4	MEDIAR ÁREAS EN LA TABLA A TRABAJAR	20/04/2022	20/04/2022
5	COLOCAR LA FAJA TRASNPORTADORA	21/04/2022	21/04/2022
6	COLOCAR LOS CILINDROS NEUMÁTICOS	21/04/2022	21/04/2022
7	COLOCAR LAS ELECTRO VALVULAS	21/04/2022	22/04/2022
8	COLOCAR LOS SENSORES CAPACITORES	23/04/2022	25/04/2022
9	COLOCAR LA FUENTE DE PODER Y PLC	23/04/2022	23/04/2022
10	COLOCAR LA LLAVE TERMICA	24/04/2022	24/04/2022
11	COLOCAR LOS BOTONES DE STAR/STOP	24/04/2022	24/04/2022
12	INSTALACION DE MANGUERA NEUMATICAS	25/04/2022	25/04/2022
13	CABLEADO	26/04/2022	28/04/2022
14	PROGRAMACIÓN DEL PLC	28/04/2022	2/05/2022

Figure 9: Gantt of the assembly of the automated machine

Author: Own elaboration

2.6. Description and detail of production indicators before automation

According to TuDashboard (n.d.), the production indicators used in this process are:

Manufacturing cost per unit: It is obtained by dividing the total number of products manufactured by each manufacturing cost, without taking into account the cost of materials. This indicator shows the most efficient way in which manufacturing inputs are used, in other words, if there is an adequate manufacturing cost between operators and production machines.

Formula: (Fixed costs+Variable costs+Administration and sales costs)/Total products produced (TPP))*100

Before automation

- Fixed costs + Variable costs + Administrative and sales costs = 100
- TPP = 90
- Manufacturing cost per unit: 111%.

Downtime in relation to Uptime: Availability is a metric used to measure the percentage of time an asset can be used. It calculates the probability that the equipment is available, without being down for preventive maintenance interventions or breakdowns, during the period in which it should be in operation.

Formula: (MTBF/ (MTBF+MTTR))*100

Before automation :

- MTBF = 8 hours
- MTTR = 4.5 hours
- Machine availability: 64%.

Yield: This indicator measures the quality level of the product. It is the number of good units that have no repairs or waste, generated in the same production. We call this indicator a good yield when the elements of the manufacturing process of the product are in good working order and there are no major problems in the quality of the material (it is preferable not to have any type of problem), and the quality and qualification of the workers are also involved.

When there are problems in the manufacturing process of the product, it means that the performance is not good or is low; if this happens, you should find out at what point you are having failures and inconveniences.

Formula: (Unit of good quantities/Unit of bad quantities)*100

Before automation

- Unit of good quantities = 90 bottles (large and small)
- Unit of bad quantities = 150 bottles (large and small)
- Yield = (90/150)*100 = 60%.

Capacity utilization: This indicator will show whether or not the production capacity is used effectively. Capacity utilization is related to the actual production that is actually produced with the equipment already installed and the maximum possible production that can be produced with the same equipment. If the rate is higher, the equipment will be used more efficiently and if the number is lower, the processing equipment will be used more efficiently.

Formula: (actual production/effective capacity)*100

Before automation: In our case our line is in charge of selecting bottle sizes and putting them in containers, below will show how the implementation made some changes.

- Actual production (actual selection) = 90 bottles (large and small)
- Effective capacity = 45
- Line utilization = 90/150 = 60%.

CHAPTER 3: CURRENT DESIGN OF PROCESS

3.1. 3D CAD drawings of the current situation.

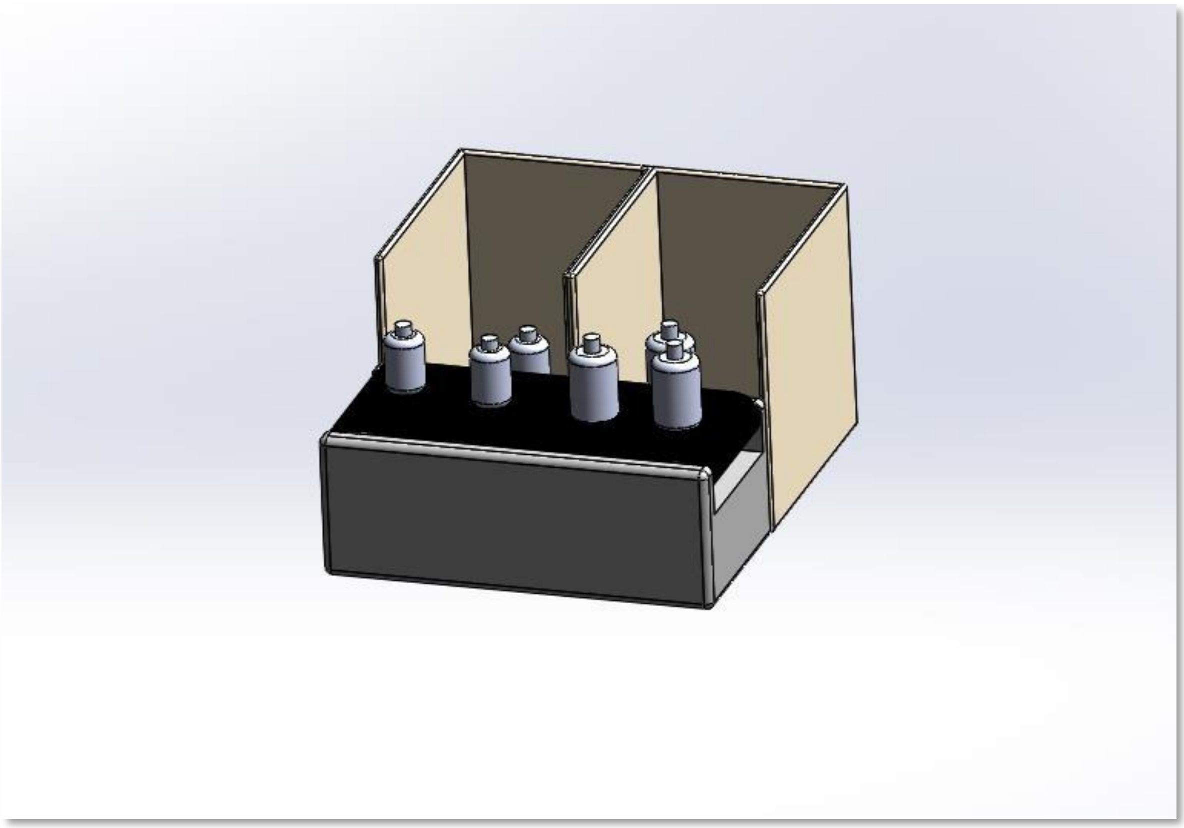


Figure 10: Plans of current situation

Author: Own elaboration

CHAPTER 4: DESIGN PROPOSAL TO AUTOMATE THE PROCESS

4.1 Detailed description of the proposed process

It is mentioned that the objective of our project is the novelty in the process of sorting bottles by size.

Our project consists of a machine based on artificial technology, which can also be used in bottling plants to efficiently clarify the bottles entering the plant. Integrated with a selective system, it classifies the bottles by size, grouping them according to their type.

Our project is programmed by classification of bottles according to size, achieving differentiation by means of the sensor at the time of execution

Therefore, the description of the process begins to be presented:

- The process of sorting bottles by size starts with the conveyor belt, which will take the bottle to the capacitive sensors where the PNP indicates the output; which is the negative potential charge and output of the detector.
- After this, the sensors start their function, where they detect the size of the product, giving the signal to the PLC; taking into account that if the piece measures different from the given height, it will continue falling into the waste box.
- From this point on, the PLC will begin to perform its function, starting with the activation of the solenoid valves.
- Then, the solenoid valves will start sending pressurized air through the pneumatic hoses to the double-acting pneumatic cylinders.
- Finally, the pneumatic cylinders begin to send pressure to the piston, thus generating the piston to bounce the product selected by the sensor into the boxes that will receive the product.
- The results are expected to show progress in the development of bottle sizing.

As highlights we will have:

. Very easy to use

. Very easy to adjust

. Efficient service

. Automatic

. Controlled by PLC program

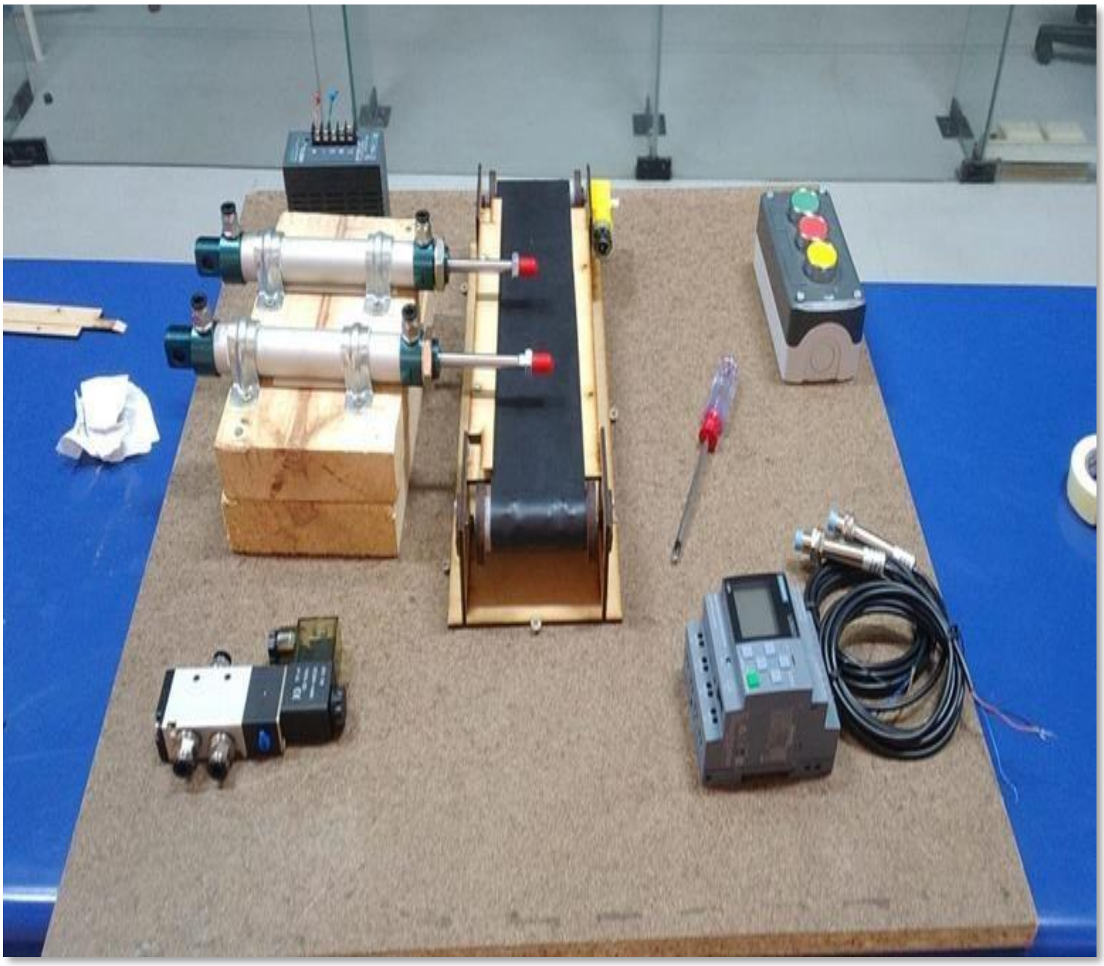


Figure 11: Bottle sorting machine Author: Own elaboration

4.2 3D CAD drawings of the chosen proposed situation (must show each component in a different color)

4.2.1. Pneumatic cable

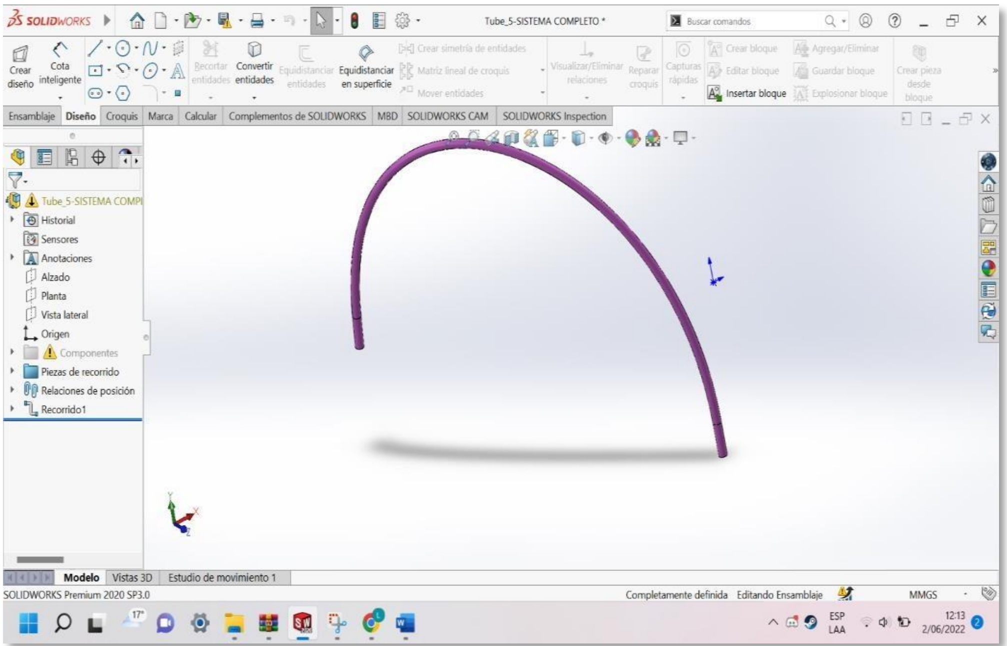


Figure 12: Pneumatic cable

Author: Own elaboration

4.2.2. Pneumatic tube

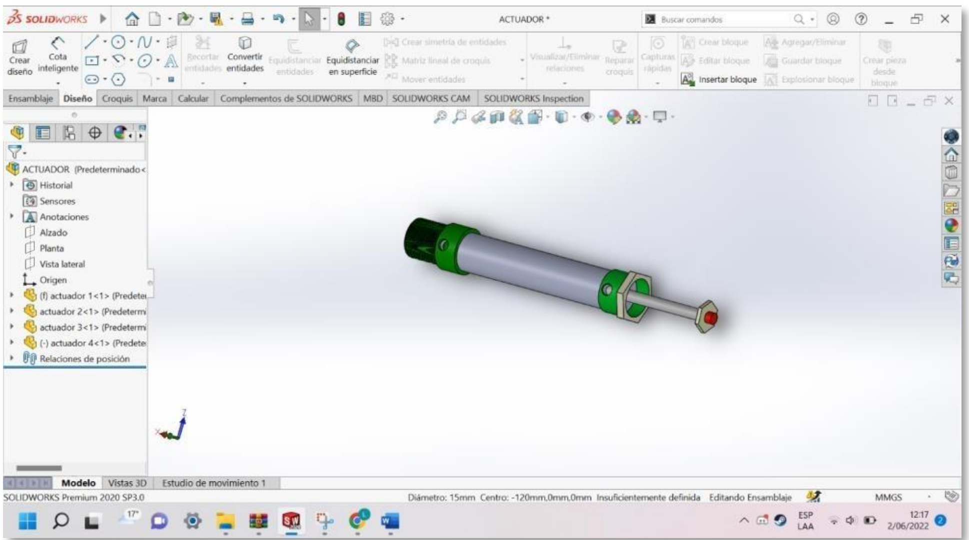


Figure 13: Pneumatic tube

Author: own elaboration

4.2.3. Solenoid valve

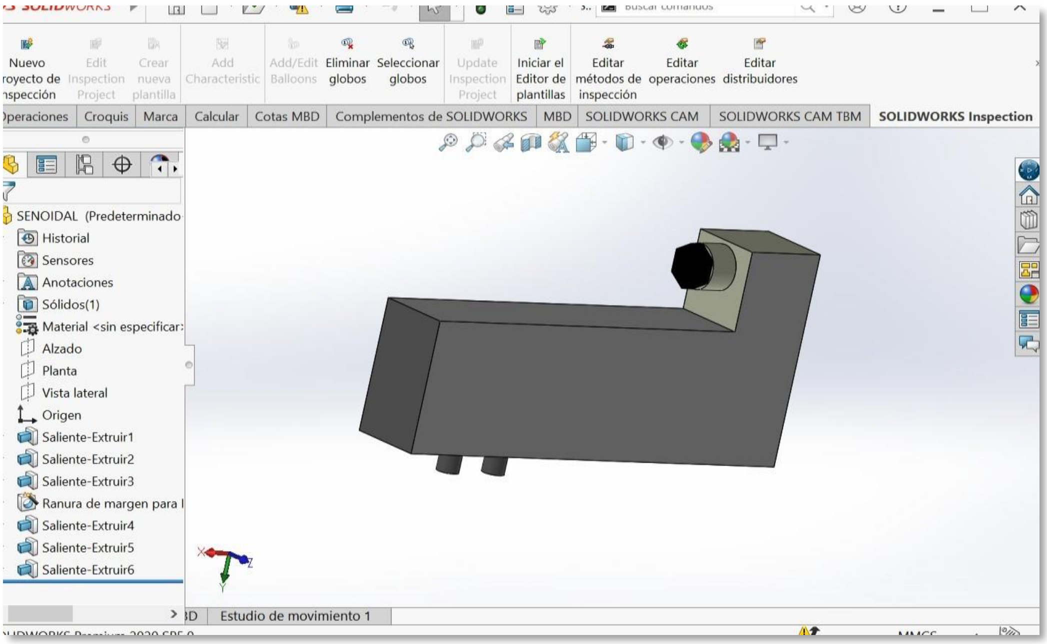


Figure 14: Solenoid valve

Author: Own elaboration

4.2.4. Conveyor Belt

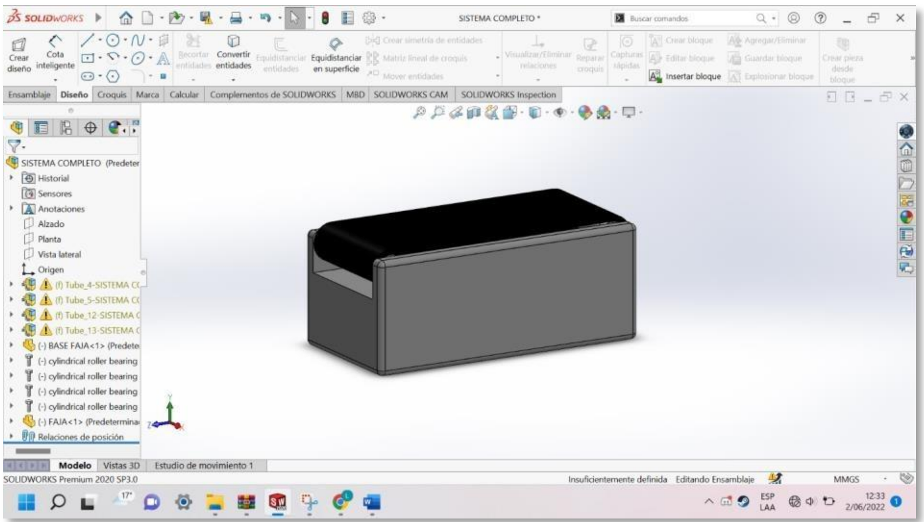


Figure 15: Conveyor belt Author:

Own elaboration

4.2.5. Material receiver

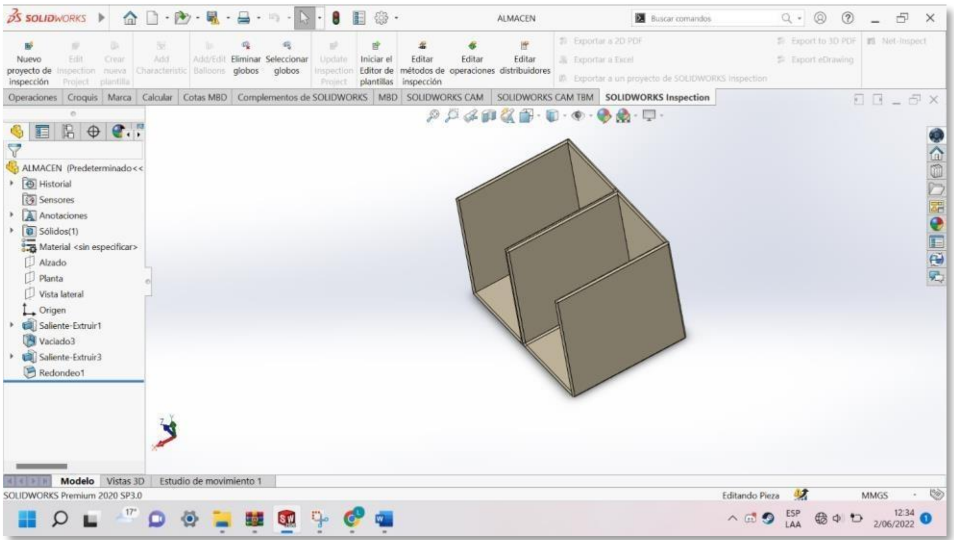


Figure 16: Receiver of materials

Author: Own elaboration

4.2.6. Pneumatic tube base

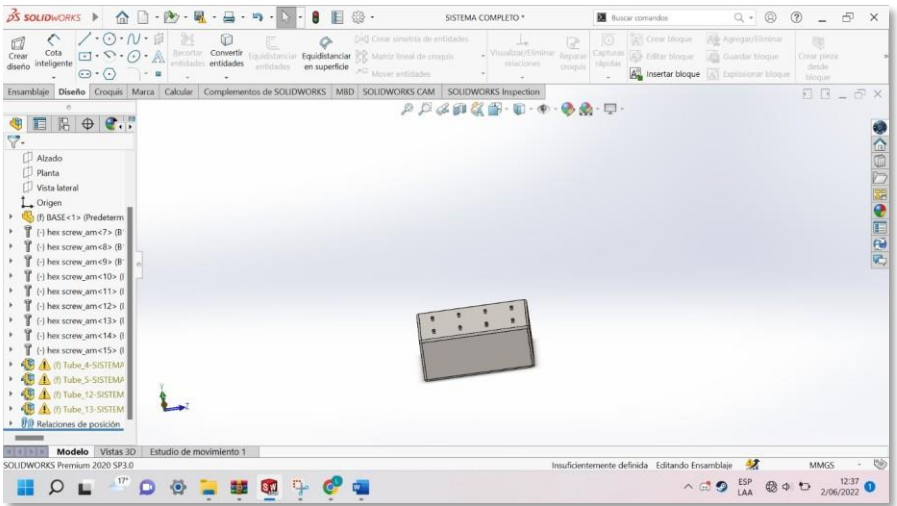


Figure 17: Pneumatic tube base Author:

Own elaboration

4.2.7. Surface

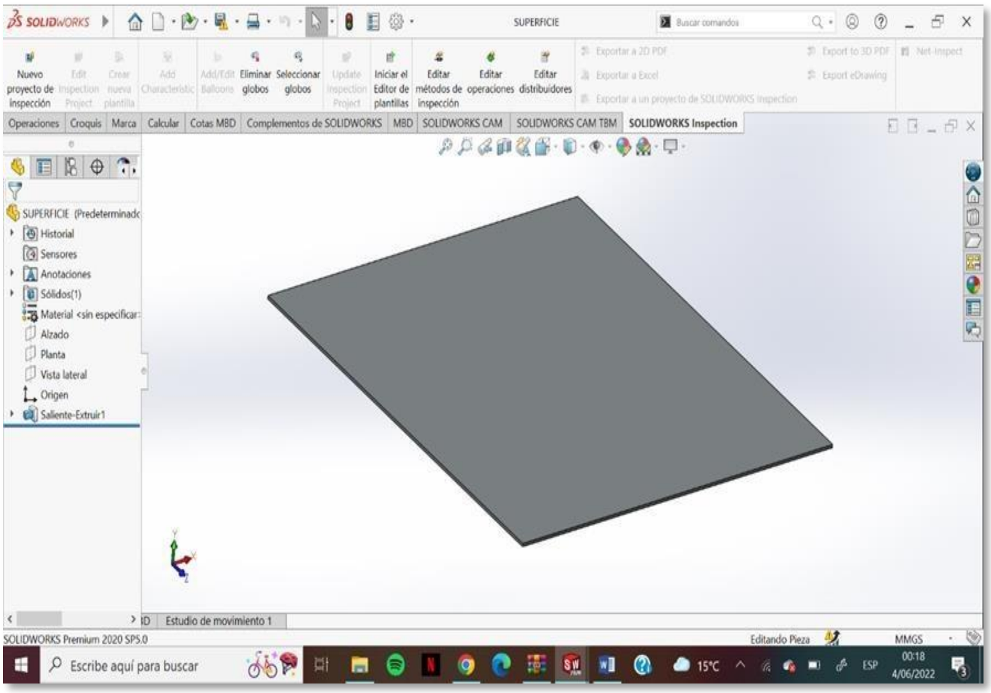
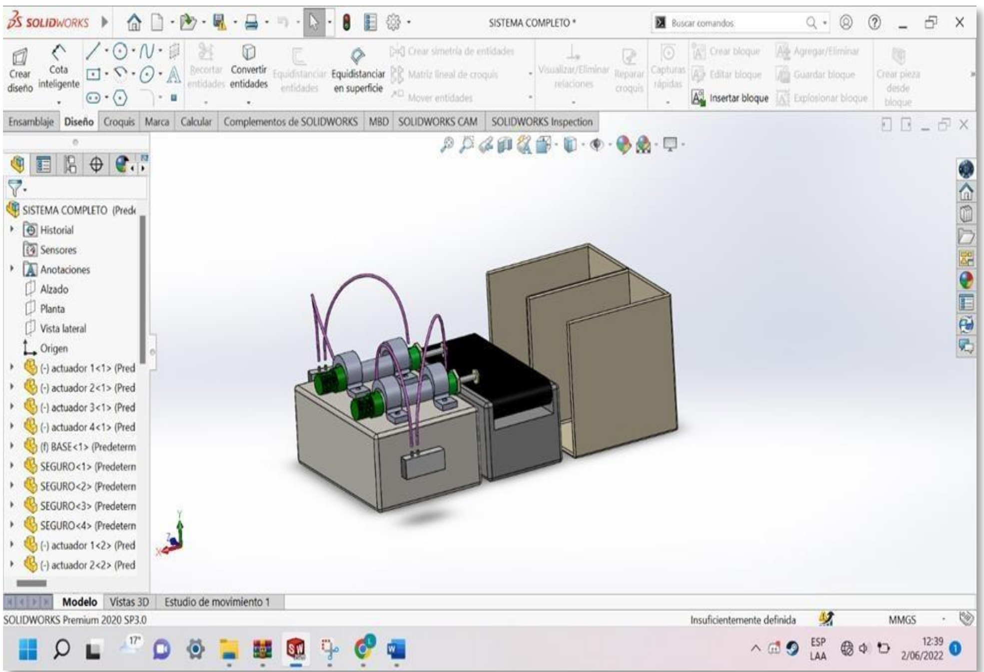


Figure 18: Surface area

Author: own elaboration

4.2.8. Complete assembly



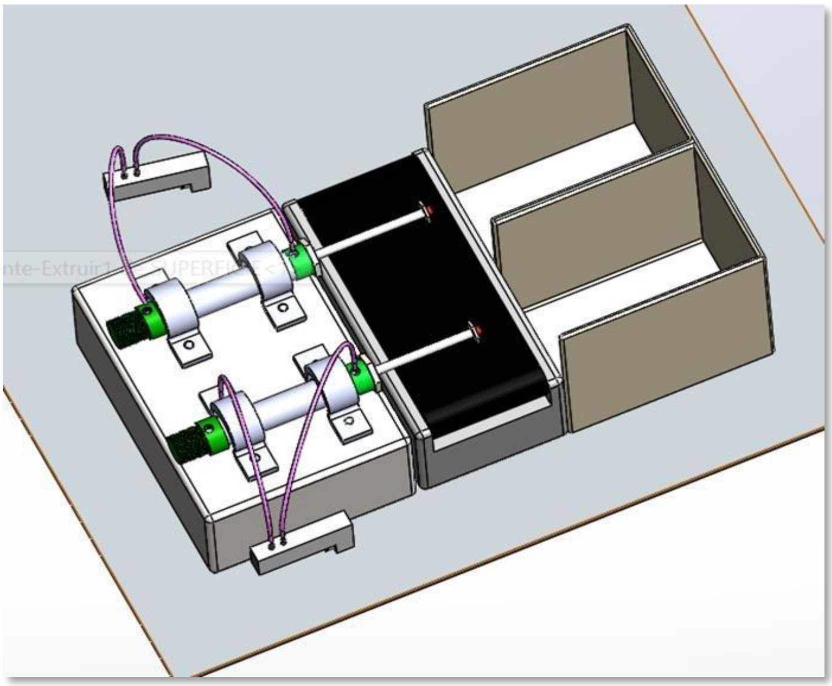


Figure 19: Complete assembly

Author: own elaboration

4.3 Flow diagrams of the proposed process

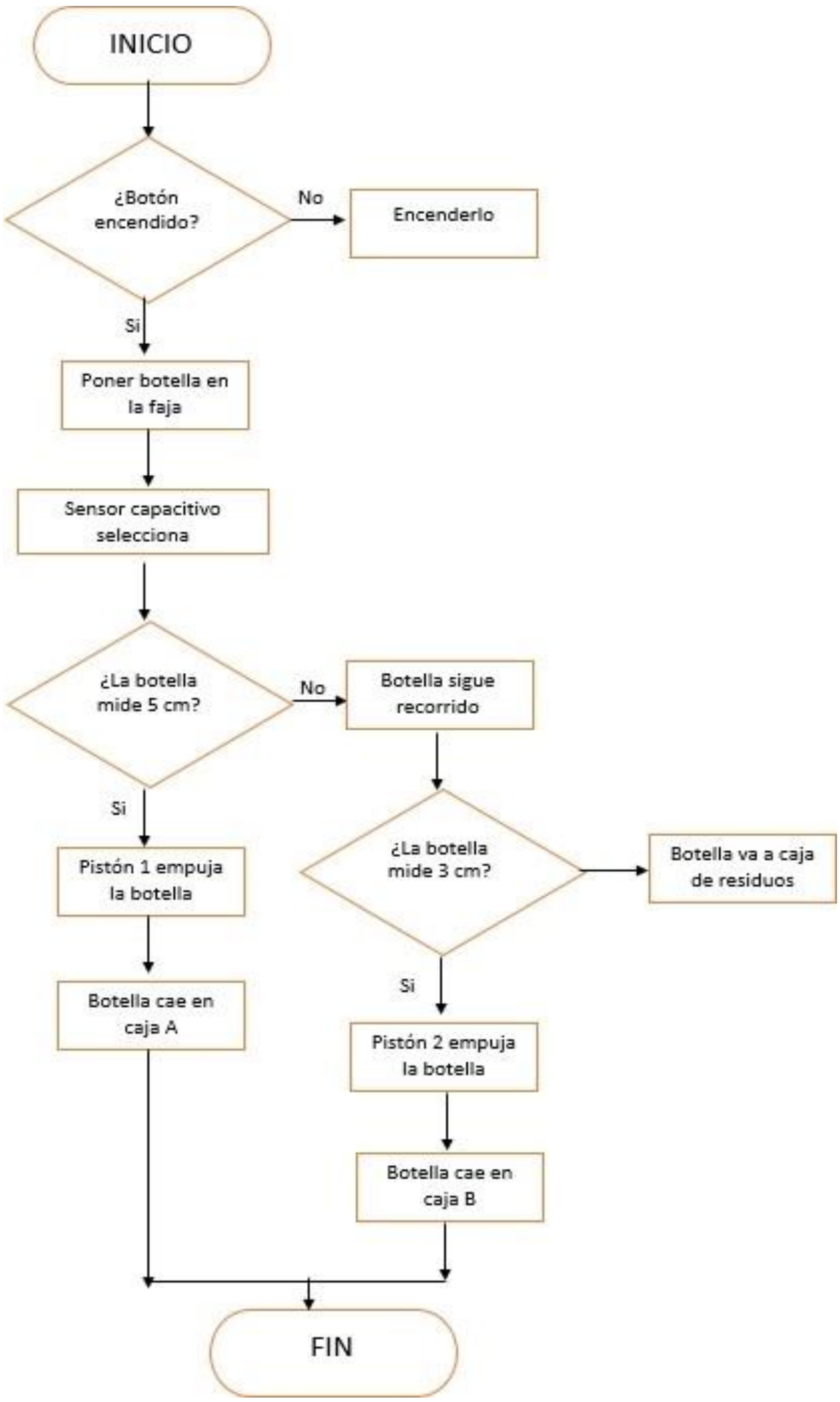


Figure 20: Proposed process flow diagram Author:
Prepared by the authors.

4.4 Operations Diagram of the proposed process

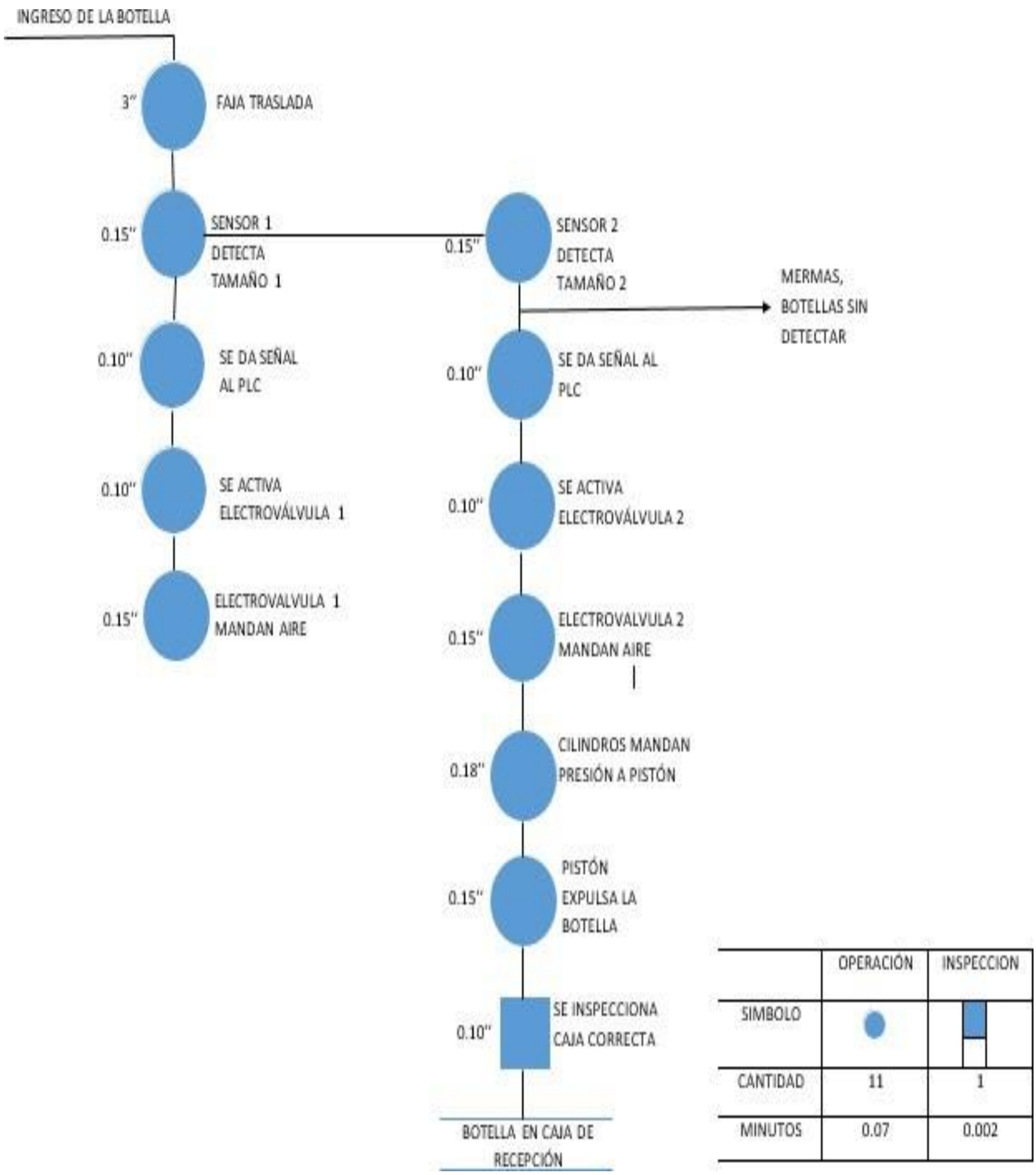
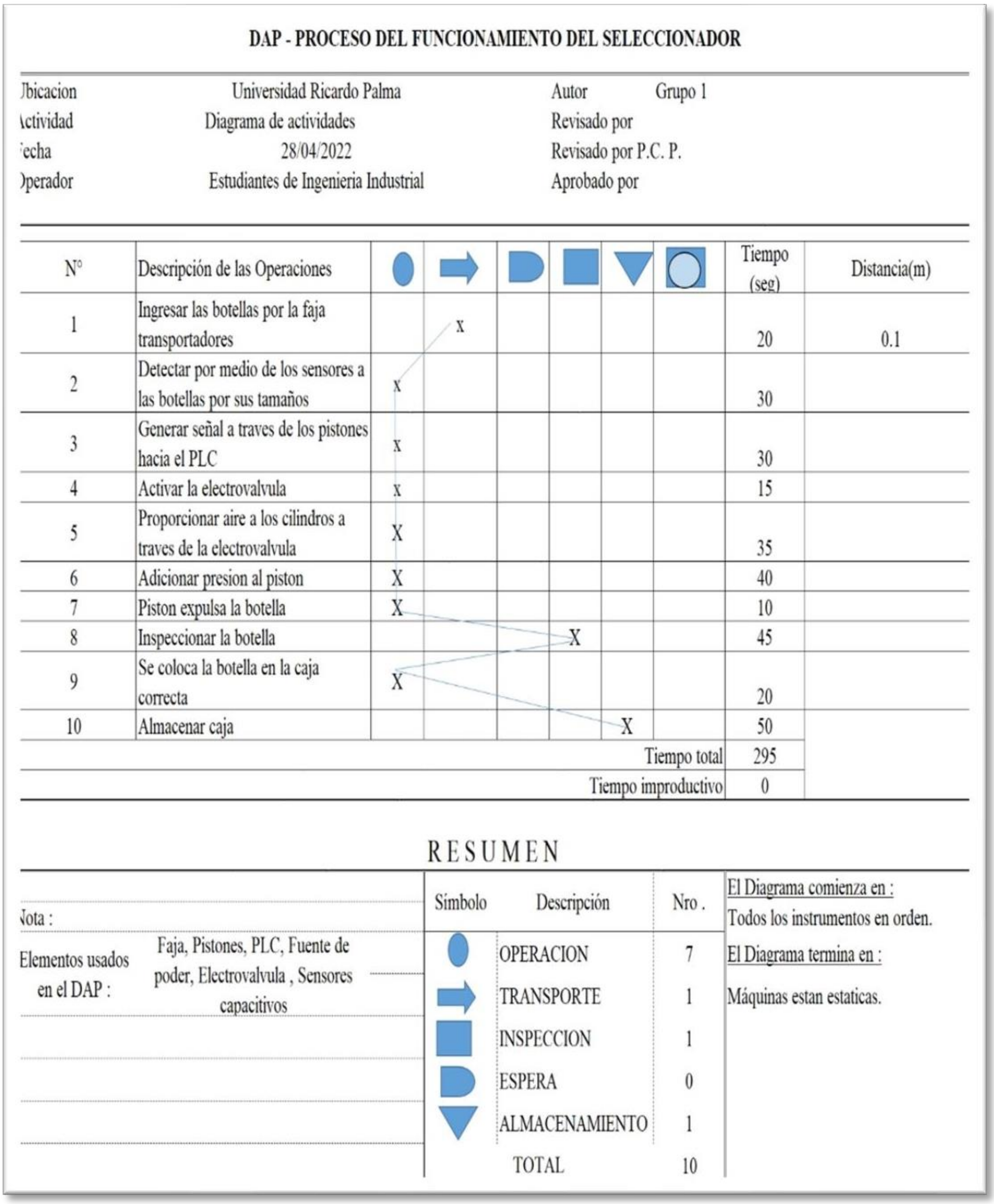


Figure 21: Operations Diagram of the proposed process

Author: Own elaboration

4.5 Process analysis diagram of the proposed process



DAP - PROCESO DEL FUNCIONAMIENTO DEL SELECCIONADOR

Jbicacion	Universidad Ricardo Palma	Autor	Grupo 1
\ctividad	Diagrama de actividades	Revisado por	
'echa	28/04/2022	Revisado por P.C. P.	
)perador	Estudiantes de Ingenieria Industrial	Aprobado por	

N°	Descripción de las Operaciones							Tiempo (seg)	Distancia(m)
1	Ingresar las botellas por la faja transportadores		x					20	0.1
2	Detectar por medio de los sensores a las botellas por sus tamaños	x						30	
3	Generar señal a traves de los pistones hacia el PLC	x						30	
4	Activar la electrovalvula	x						15	
5	Proporcionar aire a los cilindros a traves de la electrovalvula	X						35	
6	Adicionar presion al piston	X						40	
7	Piston expulsa la botella	X						10	
8	Inspeccionar la botella				X			45	
9	Se coloca la botella en la caja correcta	X						20	
10	Almacenar caja					X		50	
							Tiempo total	295	
							Tiempo improductivo	0	

RESUMEN

		Simbolo	Descripción	Nro .	
Nota :					El Diagrama comienza en : Todos los instrumentos en orden.
Elementos usados en el DAP :	Faja, Pistones, PLC, Fuente de poder, Electrovalvula , Sensores capacitivos		OPERACION	7	El Diagrama termina en :
			TRANSPORTE	1	Máquinas estan estaticas.
			INSPECCION	1	
			ESPERA	0	
			ALMACENAMIENTO	1	
			TOTAL	10	

Figure 22: Analysis Diagram of the proposed process

Author: Own elaboration

4.6 Detailed description of the materials to be used (sensors, pre-actuators, actuators, motors, PLC, etc).

Because it is a material selector, it has been chosen in

- Pneumatic cable:

  They are cylindrical cables with flexibility and made of a resistant material through which compressed air will pass to drive the pneumatic tubes by means of the compressed air.

Figure 23: Pneumatic cable
Author: Own elaboration

- Pneumatic cylinder:

  Pneumatic cylinders consist of a cylinder and piston, the cylinder's function is to guide the piston to release the energy, these cylinders are used to automate processes basically in this work the piston will be used to separate PET bottles.

Figure 23: Pneumatic cylinder
Author: Own elaboration

- Conveyor Belt:

The conveyor belt is a machine that allows continuous transport at a determined and stable speed and is made of a reinforced rubber base. Its application in this case is the transport of PET bottle material for recycling.

The operation of this consists of pulleys that are driven by motors that in our case are two double A batteries that function as the motor of the belt.

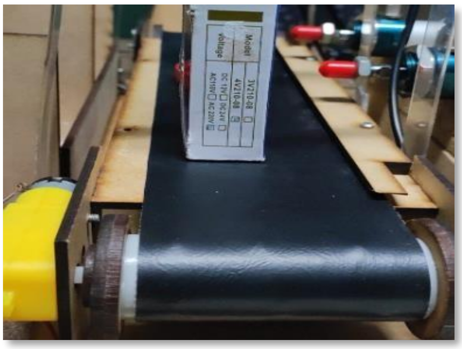


Figure 24: Conveyor belt to scale Author:

Own elaboration

- Monostable solenoid valve:

The solenoid valve gives the start and end of the circuits. The monostable solenoid valve used in this work has a coil that will cause it to reset when no signal is received.

Figure 25: Monostable solenoid valve

Author: Own elaboration

- Capacitive sensors:

The capacitive sensors are sensors that react to the approaching movement of a material to its surface, when reacting this emits a signal to the PLC that will activate the compressed air which in turn will drive the pneumatic tubes, ie capacitive sensors will be the discriminator of PET bottles.

Figure 26: Capacitive sensors
Author: AUTOTACHKI

- PLC:

The programmable logic controller better known as PLC as its name says by programming that will make the machine follow the instructions that are required either the case that by sensors are activated pneumatic tubes, ie the PLC is used to automate machines in the industry. The controller follows a central logic that through input and output interfaces, communication, the power supply of the machine and the external device.

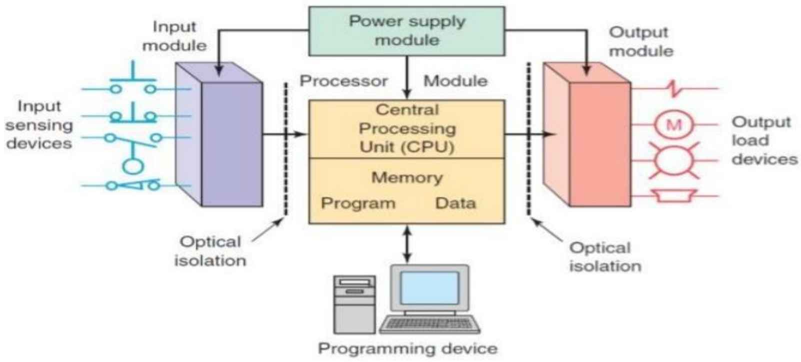


Figure 27: PLC controller logic
Author: Universidad Continental. Laboratory I of control, Taken from Gerardo, 2010.

Figure 28: PLC controller logic

Author: Own elaboration

- Air compressor:

  It is a machine that stores the ambient air and compresses it, which through its connection with the pneumatic cable and pneumatic tubes will release the compressed air that will pass through the pneumatic cable driven the pneumatic tubes, only if these capture moving through the capacitive sensors.

Figure 29: Air compressor

Author: Maskita USA

4.7 Design of the electro-pneumatic circuit of the process.

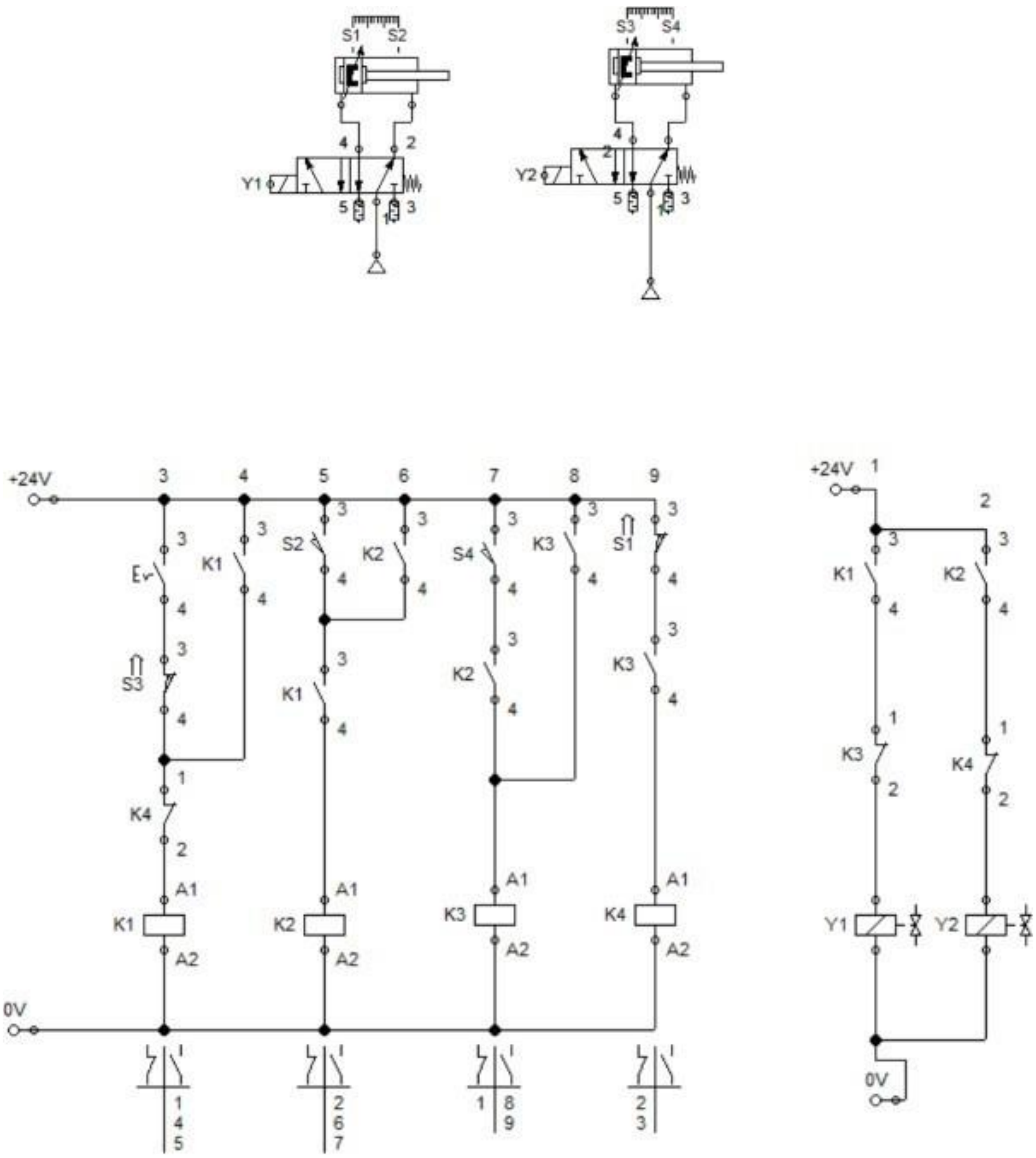


Figure 30: Circuit design Author:

own elaboration

The wiring of the power supply has a positive pole and a negative pole, these have a normal current of 220 volts, but it is transformed to 24 volts, so that the work does not explode or burn.
The sensor wiring has 3 wires, a brown, blue and black wire; the brown wire goes to the positive pole, the blue wire to the negative pole and the black wire to I3.
The wiring of the solenoid valves has two wires, one goes to the power supply and the other goes to Q1 and Q2 (the Q's are negative), but they have a positive wire that comes directly from the power supply.
The conveyor belt wiring has two wires and these are connected to a power button and AA batteries. It has 3 volts because we need an intermediate speed. As shown in figure N°32.

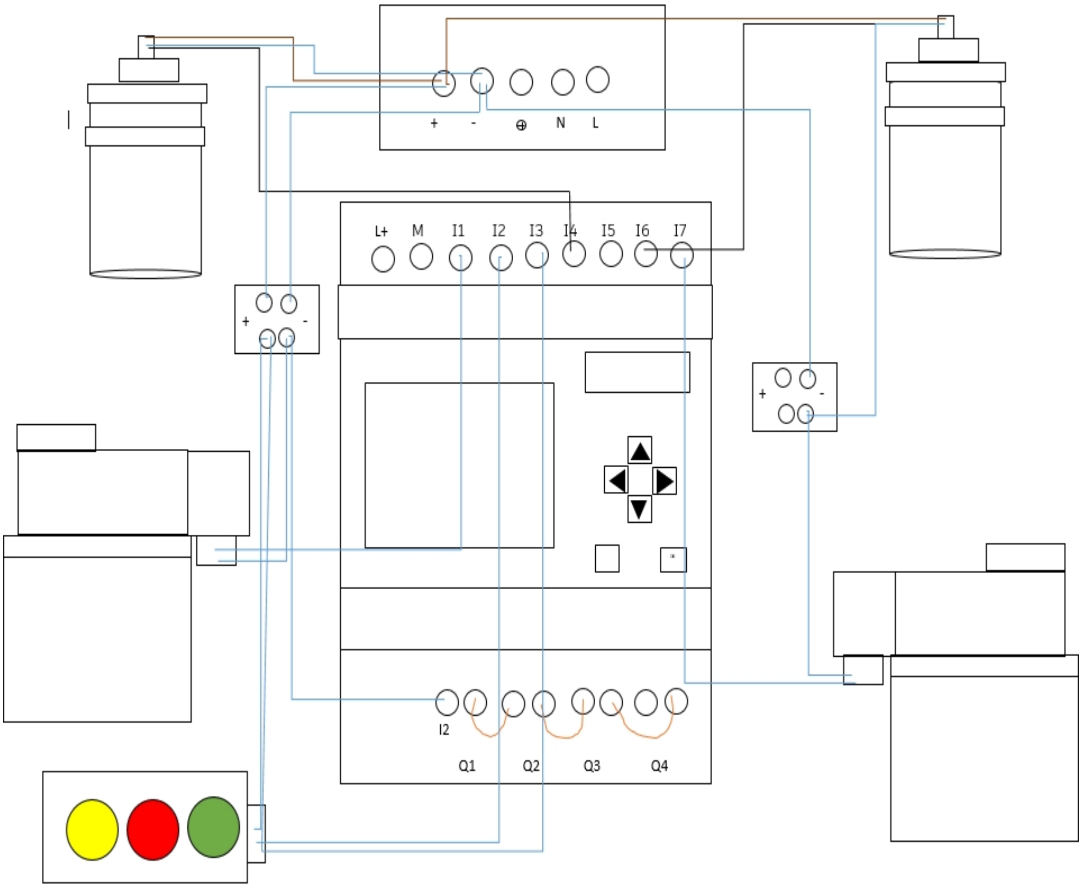


Figure 31: Wiring Author:

Own elaboration

4.8 Ladder programming of the process (comment on each of the segments used in your ladder programming).

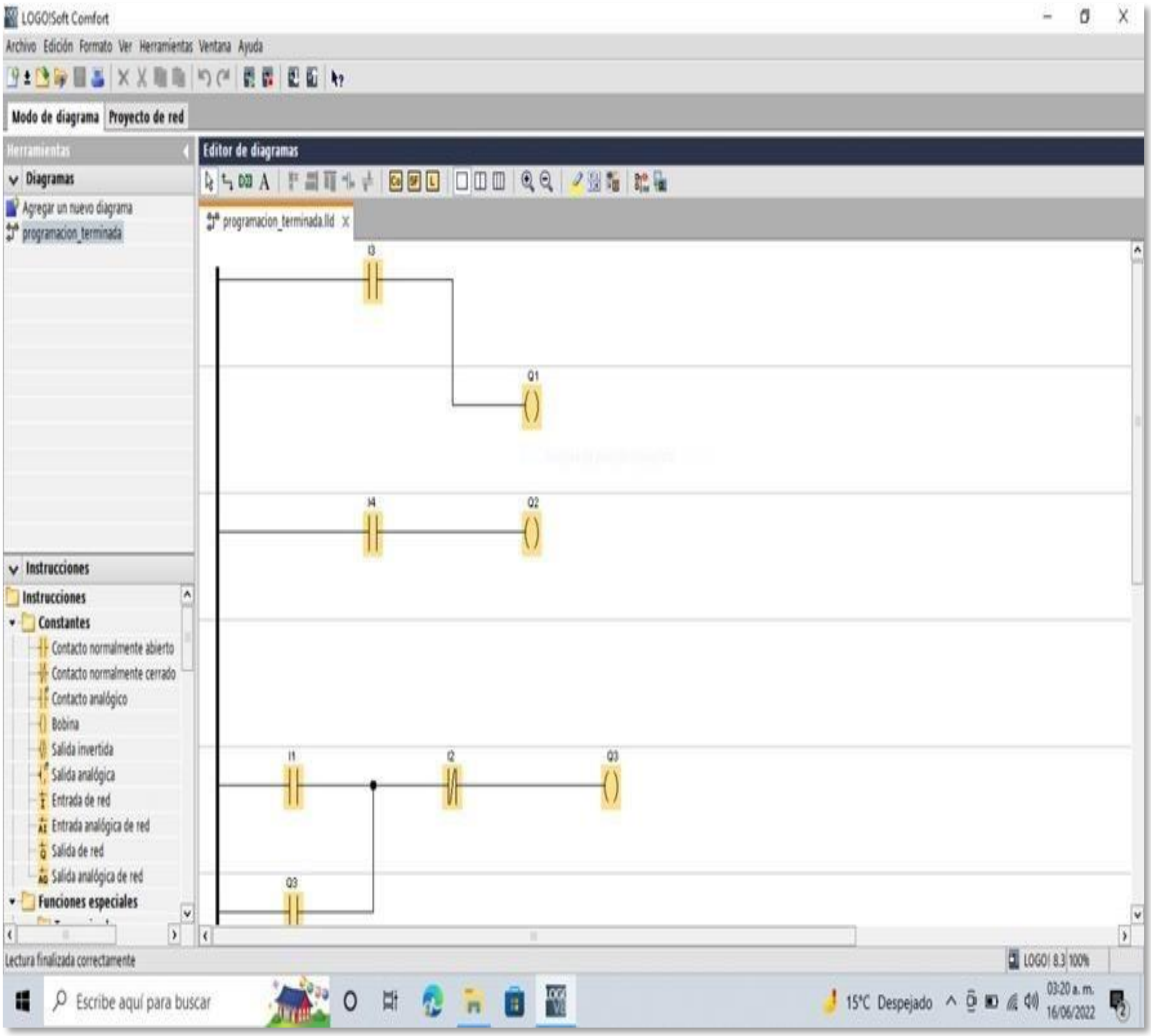


Figure 32: PLC programming

Author: own elaboration

4.9 Description and detail of production indicators after automation.

- Production cycle time

Theoretically, the production cycle time is the total time of the processes and activities that are generated in a production cycle. In our case, this time is equivalent to all the activities performed by our instruments at the moment of turning on the system. It is known that our project is a sorter so the production time starts from the moment a part is placed on the belt until the sensors and pistons help to correctly select the part, this time will vary depending on the parts we want to select. In the following figure you can visualize the packaging process in a company. If you want to calculate the time of the process, through a stopwatch is required to calculate the cycle time, to define the cycle time must be performed many sequences. Having many times, the average is then averaged to define the average cycle time, i.e. how long it would take a person on average to perform the process.

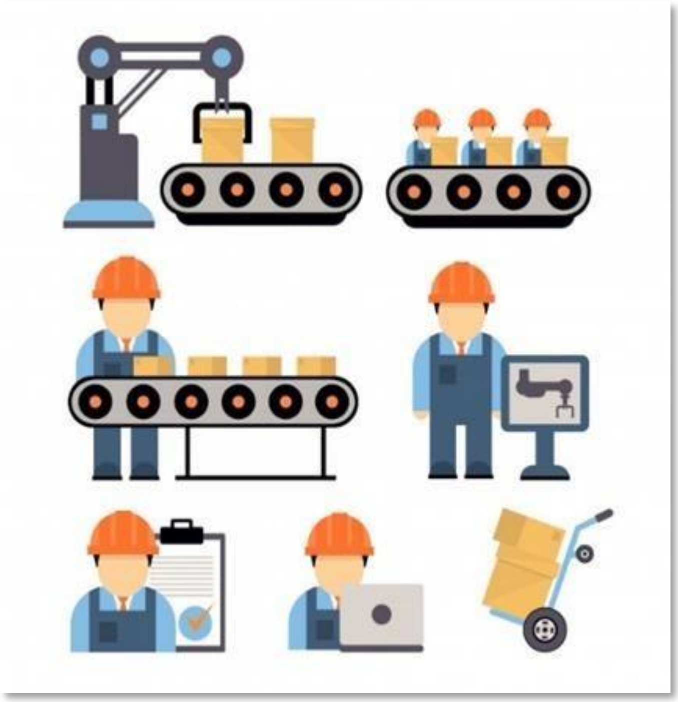


Figure 33: Packaging process Author:

Media Vuelta Digital

- Quality performance

Having previously read the textual quotations, it can be defined that quality performance is a metric that helps to evaluate customer satisfaction and process quality. There are many indicators that help to evaluate quality, for example: efficiency, effectiveness, productivity, among others. These indicators will help to numerically evaluate the quality to make it much easier to understand. In our case we evaluate the quality at the end of the process since we evaluate how many pieces have been correctly selected versus how many have not been correctly selected and by calculating these pieces we will be able to evaluate the quality of the process. We can also evaluate the quality at the end of the process by analyzing if all our parts have not been hit or broken, since the pressure provided by the compressed air makes our pistons push our parts with great force, which could cause them to break or get damaged. This is important because, if we apply our project in any food industry, the products have to be 100%. For example, in the following figure you can see how customers see the quality of the product before it is purchased.

Figure 34: Quality assessment Author:
Informa BTL

- Rejection rate

Rejection rate refers to the metric that helps to evaluate the parts that are rejected in our process. In our case, these parts are mostly rejected because they do not comply with the size established in the process. For example, we have two sensors at different sizes (one higher than the other) if we place a very small part that is not close to the sensors, they will not detect it and this part will be rejected and will be displaced along with other rejected parts. As mentioned, this is normally generated by the size of the part.

Figure 35: Evaluation of rejected products Author:
Sebastián J Brau

- Return rate

The evolution rate refers to the metric that helps us to evaluate how many returned parts have been made in the process in a certain period of time. Returns can be generated for different reasons. In general, a return is made if the product does not meet the established metrics. In our project, the return rate can be identified by the products that the sensors do not detect, but if they meet the indicated measurement, this is due to the lack of weight in the piece or the material of the product. For example, we can identify that our sensors do not detect empty boxes as they were very sensitive to detection.

Figure 36: Products returned in the United States

Author: infobae

- **Manufacturing cost per unit**

It is obtained by dividing the total quantity of goods produced by each of the monetary values of manufacturing, but not the monetary value of the main inputs to production. This measure shows the most effective possible utilization of the resources used in the operations area, therefore if there is an adequate monetary value of manufacturing between the personnel and the manufacturing machinery.

Equation: (Fixed costs+Variable costs+Administration and sales costs)/Total products produced (TPP))*100

After automation:

- Fixed costs + Variable costs + Administrative and sales costs = 85
- TPP = 120
- Manufacturing cost per unit: 70.83%.

According to Cuida tu dinero (n.d.), the indicator Period of stoppages in relation to the period of activity:

- **Period of stoppages in relation to the period of activity:**

Availability is an indicator that is used to get the percentage of time that an asset can be used. It finds the possibility of a machine being unused, minus being out of service due to the maintenance plan.

After automation:

Equation: (MTBF/ (MTBF+MTTR))*100

- MTBF = 9 hours
- MTTR = 5.5 hours
- Machine availability: 62.06%.

According to DispatchTrack (n.d.), the performance indicator is:

- **Quality performance by size or rejection rate:**

In this manufacturing KPI your priority is to diagnose the percentage of manufactured items that at the end of their production did not get faults. In other words, the number of finished goods after processing that a r e i n t h e condition approved by the manager and the customers.

Equation: (Unit of good amounts/Unit of bad amounts)*100

After automation

- Unit of good quantities = 110 bottles (large and small)
- Unit of bad quantities = 130 bottles (large and small)
- Yield = (110/130)*100 = 84.61%.

According to Valuekeep (n.d.), the capacity utilization indicator is:

- **Capacity utilization:**

It is the measure of manufacturing of the machinery comparing the total measure of manufacturing of the whole manufacturing line. An example, in the production area it is known that one of the machinery manufactures 80 items per hour, however the work of the other equipment decreases the work of the line to manufacture a measure of 45 items per hour, then the degree of effectiveness is 56.25%.

Equation: (real production/effective capacity)*100

In our case our line is in charge of selecting the sizes of the bottles and putting them in containers, below we will show how the implementation made some changes.

After automation:

- Actual production (actual selection) = 120 bottles (large and small)
- Effective capacity = 150
- Line utilization = 120/150 = 80%.

4.10 Industrial safety aspects after the implementation of the proposal

Taking into account the industrial safety aspects that will be implemented in this project, we will proceed to establish the policies and procedures that apply to the project.

Therefore, we will start with:

- Create a preventive manual, where the guidelines will have to describe the moments where the use of safety implements is necessary, in order to avoid accidents in the work area. These EPPS are very basic and necessary, they should always be used as a preventive act. The most common are glasses, helmet, gloves, boots, ear muffs, special clothing for work (reflective clothing).

These are the basic implements to have for work, but there are more with higher specifications and special for different types of work.

Without this protective equipment, hazards become accidents and can even result in the death of workers.

Adding in a brief way the descriptions of the PPE (Personal Protective Equipment) that will be used at the moment of developing an activity.

.

Figure 37: Personal Protective Equipment

Author: 123RF

Some of the protective equipment includes the following:

- Helmet: These help to protect the head from blows.

Figure 38: Hull

Author: 123RF

- Gloves: They serve to protect the hands.

Figure 39: Protective gloves

Author: 123RF

- Lenses: They serve to protect vision.

Figure 40: Safety glasses Author:

123RF

- Boots: They are used to protect the feet from blows.

Figure 41: Boots

Author: 123RF

- Reflective vest: Used to protect and warn others.

Figure 42: Vest

Author: 123RF

- Establish security policies, where the SSOMA managers will be involved. These will have as main function the implementation and compliance with the established rules, this is mandatory and of primary concern. These safety policies must be complied with and communicated to all workers, as this way they will be complied with to the letter and there will be no problems with the implementation and/or compliance of these.

Figure 43: SSOMA meetings

Author: Grupo Caresny Perú

- Avoid improvisations of material, do not want to invent tools or modify tools already prepared for an event, since this can cause very serious accidents, such as blows, bruises, fractures, injuries, damage to infrastructure, and in other regrettable cases, can even cause death. Improvisations are usually made by new or inexperienced employees, so it would be good for them to be trained to start working in the indicated area, in order to avoid problems and accidents.

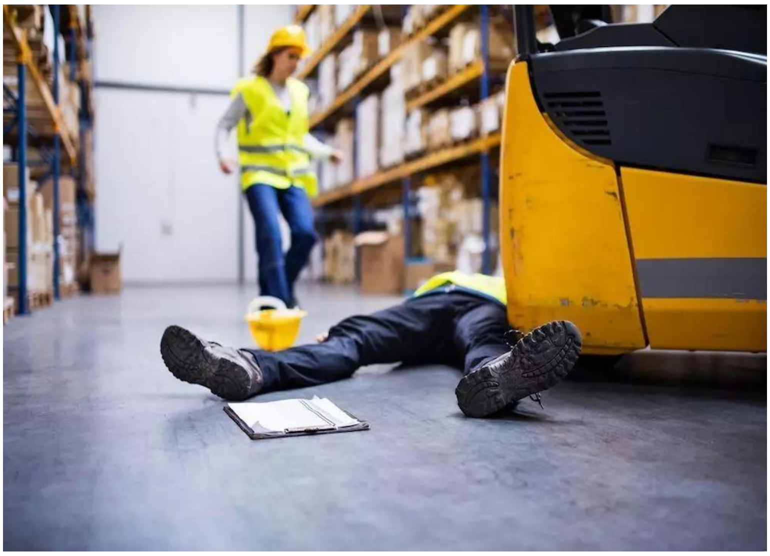


Figure 44: Workplace Accidents

Author: The Logistic World

CHAPTER 5: INVESTMENT COSTS AND OPERATING COSTS

5.1. Cash flow

For the realization of the cash flow it must be taken into account:

- Project investment:

  Table 1 shows the manufacturing costs of the machine.

Table 1: Machine Manufacturing Costs

MATERIAL INVESTMENT COSTS			
MATERIALS	QUANTITY	PRICE	TOTAL
Capacitive sensors 24 V pnp 3-wire	2	S/ 65.00	S/ 130.00
PLC	1	S/ 600.00	S/ 600.00
Solenoid valve 5/2 monostable	2	S/ 50.00	S/ 100.00
Screw, nails and L-brackets	1	S/ 15.00	S/ 15.00
Piston 20 x 100 aluminum	2	S/ 90.00	S/ 180.00
Power supply	1	S/ 80.00	S/ 80.00
Cable	1	S/ 18.00	S/ 18.00
6 mm hose	3	S/ 2.50	S/ 7.50
Green pushbutton	1	S/ 6.00	S/ 6.00
Red pushbutton	1	S/ 6.00	S/ 6.00
Yellow pushbutton	1	S/ 6.00	S/ 6.00
Box with 3 holes	1	S/ 20.00	S/ 20.00
Redos 6 mm	1	S/ 4.00	S/ 4.00
Redos ¼ x 6 mm	6	S/ 5.00	S/ 30.00
Redos ⅛ x 6 mm	4	S/ 5.00	S/ 20.00
Tripley board to make the boxes	1	S/ 25.00	S/ 25.00
Cuter	1	S/ 2.00	S/ 2.00
Silicone	1	S/ 1.00	S/ 1.00
Acrylic plastic	1	S/ 30.00	S/ 30.00
Battery box + batteries	1	S/ 15.00	S/ 15.00

Base board + 2 timbers	1	S/ 40.00	S/ 40.00
Adapter with internet connection	1	S/ 25.00	S/ 25.00
Conveyor belt	1	1S/ 80.00	S/ 80.00
OPERATING INVESTMENT COSTS			
Laser cutting	1	S/ 10.00	S/ 10.00
INVESTMENT COSTS IN OTHER EXPENSES			
Tickets	1	S/ 80.00	S/ 80.00
TOTAL			S/ 1,530.50

- Depreciation

  The machine is depreciated using the SDA method, its useful life is 10 years, and its residual value will be 15% of the initial price.

VALOR DE VENTA	2000.00
VIDA UTIL	10 años
VALOR RESIDUAL	15%

CONTROL DE ACTIVOS

INVERSIÓN	
Total de inversión	**1530.00**
VR= 15%X2000=	**300.00**

DEPRECIACIÓN

$$\frac{VL - VR}{\#AÑOS} = \frac{1530 - 300}{10} = \mathbf{123.00}$$

Table 2: Machine depreciation

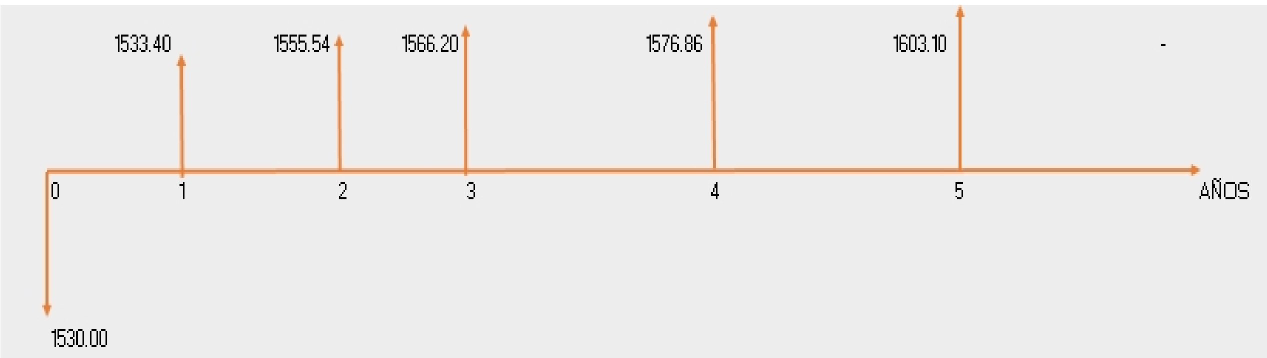
	0	1	2	3	4	5
MAQUINA	1530	1407.00	1284.00	1161.00	1038.00	915.00
DEPRECIACIÓN		123.00	123.00	123.00	123.00	123.00

The market value over the last 5 years will be taken to be a total of 3,000

VALOR DE MERCADO DE 5º AÑO	3000
TASA IMPOSITIVA	20%

RAF (5ªAÑO) = VM - (VM-VL)X Tx = 3000-(3000 - 915.00)x20% = **2583**

	AÑO 0	AÑO1	AÑO 2	AÑO 3	AÑO 4	AÑO 5
INGRESOS		1570	1597	1610	1623	1655
INVERSIÓN	-1530.00					
COSTOS DE PRODUCCIÓN		-950	-950	-950	-950	-950
DEPRECIACIÓN						
MÁQUINA SELECCIONADORA		-123.00	-123.00	-123.00	-123.00	-123.00
UTILIDAD IMPONIBLE		1693.00	1720.00	1733.00	1746.00	1778.00
IMPUESTO A LA RENTA		282.6	287.46	289.8	292.14	297.9
UTILIDAD DISPONIBLE		1410.40	1432.54	1443.20	1453.86	1480.10
DEPRECIACIÓN		123.00	123.00	123.00	123.00	123.00
RAF						2583
FLUJO EFECTIVO NETO	-1530.00	1533.40	1555.54	1566.20	1576.86	1603.10



5.2. Economic viability

To determine the economic viability of the sorting machine, data obtained from cash flow will be used.

COK= 15%.

CÁLCULO TIR

1530= 1533.40*FSA(i,1) + 1555.54*FSA(i,2) + 1566.20*FSA(i,3) +1576.86*FSA(i,4) + 1603.10*FSA(i,5)

TIR = 97.88%

CÁLCULO VAN

VAN= - 1530+ 1533.40*FSA(0.15,1) + 1555.54*FSA(0.15,2) + 1566.20*FSA(0.15,3) + 1576.86*FSA(0.15,4) + 1603.10*FSA(0.15,5)

VAN = S/3,708.00

TIR = 97.88%

VAN = S/ 3708.00

With these indicators we will be able to realize that the development of the machine is feasible.

CONCLUSIONS

1. It is concluded that the implementation of this project may in the future help in the classification of bottles by size, since it is a prototype that fulfills its function correctly, thanks to the correct wiring and programming it was possible to achieve the objectives of the project.
2. Order and cleanliness in the work space will be of great help to carry out the project since working with different tools such as drills, cutters, screwdrivers, among others. The order will help to advance in a correct and safe way the assembly of the project.
3. This machine was a good investment because with a useful life of 10 years, its value will only reduce by 15% of the initial price. In other words, it could be sold and a better one obtained.
4. Throughout the project we were able to implement different techniques and learning acquired in the Industrial Automation course, this knowledge can be applied in the future in a company and in a real case.
5. Cosimir software helps to establish a connection between the physical project and the schedule, so that the project can be managed correctly and continuously.

RECOMMENDATIONS

1. It is recommended that at the moment of purchasing the materials a previous quotation is made and a comparison is made with the other prices in the market, in this way the initial budget can be reduced or the quality of some materials can be improved. The fact of comparing and seeing the prices and the quality of the different materials to be used will help in the first part of the project process, having all the materials ready you can proceed to its realization.
2. The use of personal protective equipment is recommended since the project involves working with electricity, which can be dangerous for the operator.
3. An important recommendation is to cover the cables coming out of the power source, since if the proper care is not taken and safety devices are not used, they could be electrocuted on contact.
4. When connecting the solenoid valves, make sure that the light bulb turns on; if it does not turn on, it means that it is not properly installed.
5. Another recommendation to ensure that the project works properly is to secure the pneumatic cylinder adapters in order to avoid air leaks.
6. It should be noted that capacitive sensors emit a sound on contact with the bottle, if this does not occur is because something is wrong with the wiring, it is recommended to thoroughly review all the details.
7. With respect to the conveyor belt, it is recommended to adapt a voltage of 3 V to the conveyor belt, otherwise it will have too much speed and the sensors will not capture the bottles and the project will not develop properly and may even take time in the realization of this.
8. When fixing the pneumatic cylinders, first make sure that they are driving the cylinders to their correct receiver box.
9. Follow the area distribution measures for each part of the project to avoid short circuits.
10. It is recommended to follow an order in the programming to avoid that Cosimir software detects failures or that the actions we want to implement for the development of the physical project are not carried out.
11. Finally, it is recommended to thoroughly check the small details of the project, whether it is the wiring, the programming or the installation of each of the components, since it is these small details that prevent the project from being carried out efficiently.

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