UNIVERSIDAD RICARDO PALMA

ENGINEERING FACULTY

PROFESSIONAL SCHOOL OF INDUSTRIAL ENGINEERING

RESEARCH WORK

INDUSTRIAL AUTOMATION

"Design and development of an automatic classification system."

MEMBERS

- **Flores Galvez, Josué Daniel**
- **Hidalgo Llerena, Piero Aymar**
- **Lizarraga Galindo, Pool André**
- **Rojas Rodríguez, Iván Francisco**
- **Saavedra Briones, Janett**
- **Sarmiento Camacho, Axel**
- **Vallejos Mavila, Miluska**
- **Quiroz Bonifacio, Giancarlo**

Teacher: Dr. José Antonio Velásquez Costa

Lima - Peru

2022-II

INDEX

INDEX OF FIGURES

TABLE INDEX

INTRODUCTION

In this project we will elaborate the automation of an object transport and storage process by designing and building a product classification system with a conveyor belt and optical sensors.

The automation is intended to be implemented in the Winflex company, providing support in the sorting and packaging process. For this purpose, we define the processing processes, characteristics of the station, sketch, project diagrams and production indicators.

In the following chapters we will see the theoretical foundation that involves the project along with its objectives. We will also mention the detailed description of the process that we want to automate, attaching diagrams that will facilitate the understanding of the current process, on the other hand, we will see the production indicators, quotation and the outline of the automated process.

We will mention the detail of the design proposal to automate the process, we attach diagrams that will help the understanding of the automated process, along with the detailed description of the materials used, the design of the electro-pneumatic circuit and the PLC programming.

CHAPTER 1 - THEORETICAL FRAMEWORK

1.1. Theoretical basis

1.1.1. Industrial automation

Industrial automation refers to the use of control systems such as computers, programmable logic controllers, robots and information technology. This responds to the different production processes and machinery in industry, largely eliminating human intervention and replacing dangerous assembly operations with automated operations.

1.1.2. Processes

A set of successive phases comprising a system of a natural manifestation or of a human-made intervention.

1.1.3. Industrial Processes

Industrial processes are known as the set of stages that transform raw materials into goods or final products. Generally, goods are produced in large quantities and are intended to be consumed by a large target public.

1.1.4. Process automation

The automation of industrial processes refers to the use of technology to execute recurring tasks or processes in a company. This makes it possible to minimize costs, increase efficiency and streamline processes that are increasingly complex for humans.

1.1.5. Automated System

Automated systems are "solutions" that companies implement for greater efficiency in their operational processes, is a system in which the production tasks usually performed by the operator are transferred to a set of technological elements, and has two important parts, the control, and usually the technology. The process will become the heart of the system, it must be able to communicate with the different parts of the automation system and the actuator, the part that works in the machine, i.e. the elements that make the machine work.

the machine changes. Outside of operations, these are the actuators of machines such as motors or compressors.

1.1.6. PLC

Programmable Logic Controllers (PLC) are industrial computers used in industrial automation. These computers are basically in charge of processing data from industrial machines. PLC is equivalent to the brain of the machine. It activates the machine components to perform a specific activity, i.e. it automates the machine or the machine's actions.

A PLC consists of three basic elements: inputs, outputs and a CPU.

It is responsible for processing the data from the machines. Well, the data it receives comes from the input. This data comes from sensors, timers, thermometers, etc.

After the data receives the input, it reaches the CPU of the device, which is the brain of the PLC, processes the input information and sends a corresponding output signal. Subsequently, thanks to relays and contactors, they activate another device, such as a valve, motor, lamp, piston.

1.1.7. Photoelectric sensors

A photoelectric sensor is a device used to detect the presence or absence of a nearby object, it responds to the change in light intensity. Sensors need some emitter component that generates sufficient light, and a receiver that detects the light generated by the emitter, all types of sensors work on this principle of operation.

Photoelectric sensors are designed for detection, positioning and classification of objects, detecting colors, shapes and the material of which the objects are made.

1.1.8. Electrical circuits

An electrical circuit is an interconnection of electrical elements that are connected to each other and that transport, generate and use electrical energy in order to transform it into another type of energy.

1.1.9. Electropneumatics

Electro-pneumatics is a process or technique in which electricity replaces pneumatic energy in control systems. In conclusion, electro-pneumatics takes control of pneumatic elements.

1.1.10 Pneumatic piston

Pneumatic cylinder or pneumatic piston is a mechanical device that transforms the potential energy of compressed air into kinetic energy.

1.1.11. Automatic sorting

Automatic classification can be defined as the action performed by an artificial system on a set of elements to sort them into classes or categories.

1.1.12. Innovation

Innovation is a transformative action based on novelty. Innovation is often associated with the exploration of progressive ideas and new ways to improve something that already exists, solve a problem or advance an activity based on previous knowledge.

1.1.13. Efficiency

Efficiency is the ability to achieve results by optimizing the use of resources. It can also refer to the completion of a job in a shorter period of time. An efficient process can be said to be a process that is achieved with the least amount of resources for the greatest benefit.

1.1.14. Environmental Care

Environmental care represents all the actions that living beings must take to preserve the health of nature. The goal is to turn it into an environment with more opportunities and more benefits, satisfying the life of all generations.

1.1.15 Engineering

Engineering is the profession in which scientific and empirical knowledge is applied to optimize the transformation of materials and natural forces into practical uses for human beings, and for the invention, improvement and use of industrial technologies and to solve technological and social problems. It is considered an art because human imagination and creativity come to the fore to conceive things that do not yet exist and by applying their scientific knowledge they transform these ideas into action or reality.

1.2. Objectives

1.2.1 General Objective:

Pilot design of an automatic sorting station with optical sensors that detect the size of parts and according to this property classify them accordingly in different warehouses.

Specific objectives:

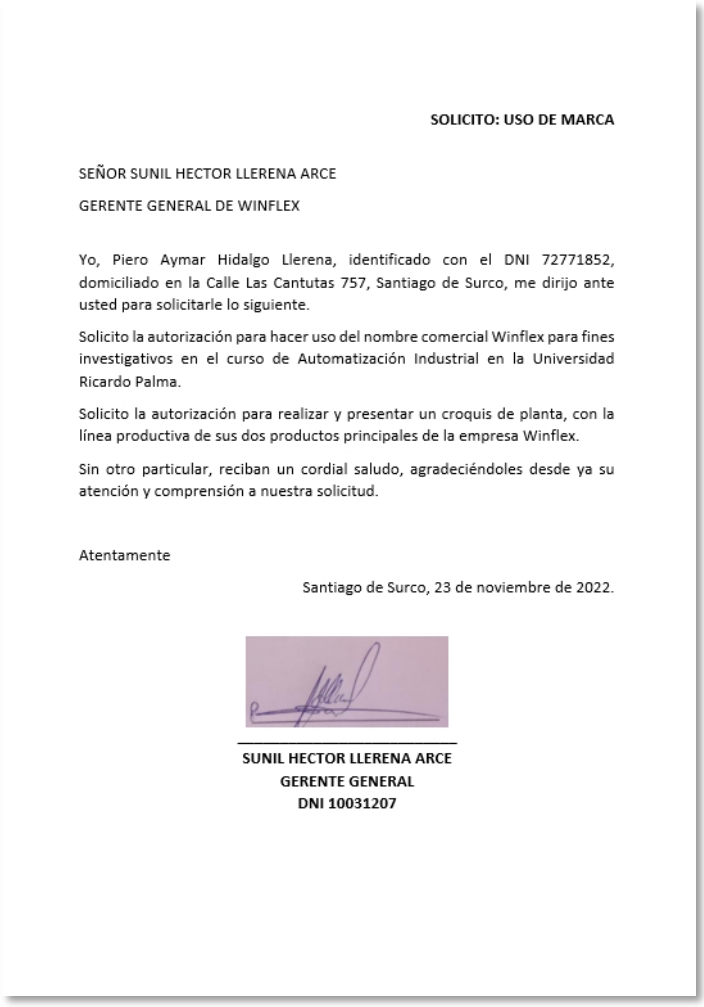
- Explain the correct operation of the project components.
- Explain the profitability of this project.
- Explain the impact generated by its application in the company and in society.

CHAPTER 2 - DESCRIPTION OF THE CURRENT PROBLEMS

2.1. Description of the current process

The Winflex company classifies its two products by size, being its products the cable winch and the sandpaper adapter for broom, both products have a similar process in 6 work stations, culminating the process in the packaging area, in this area both products are stacked and an operator classifies them in different boxes for future packaging.

The authorization to use the information of the Winflex company, signed by the General Manager, is also attached.



SOLICITO: USO DE MARCA

SEÑOR SUNIL HECTOR LLERENA ARCE

GERENTE GENERAL DE WINFLEX

Yo, Piero Aymar Hidalgo Llerena, identificado con el DNI 72771852, domiciliado en la Calle Las Cantutas 757, Santiago de Surco, me dirijo ante usted para solicitarle lo siguiente.

Solicito la autorización para hacer uso del nombre comercial Winflex para fines investigativos en el curso de Automatización Industrial en la Universidad Ricardo Palma.

Solicito la autorización para realizar y presentar un croquis de planta, con la línea productiva de sus dos productos principales de la empresa Winflex.

Sin otro particular, reciban un cordial saludo, agradeciéndoles desde ya su atención y comprensión a nuestra solicitud.

Atentamente

Santiago de Surco, 23 de noviembre de 2022.

SUNIL HECTOR LLERENA ARCE
GERENTE GENERAL
DNI 10031207

Figure 1: Authorization for use of Winflex trademark

2.2. Sketch of floor plan

Measurements of the Winflex manufacturing plant were taken.

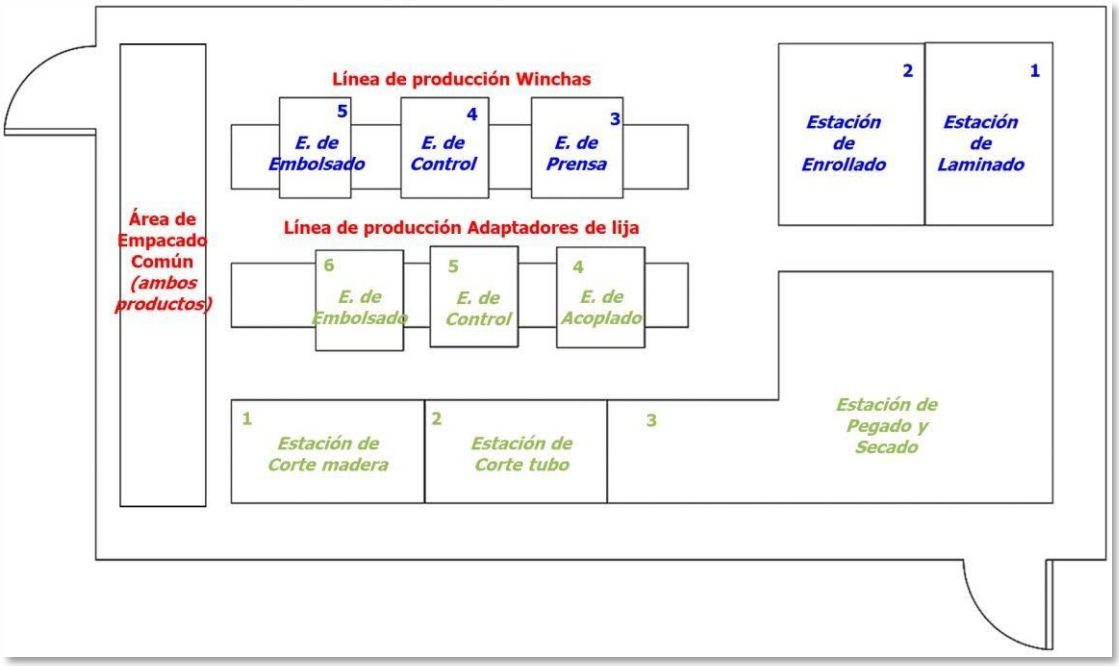


Figure 2: Sketch of the Winflex company's plant: Own elaboration

The cable winches pass through the rolling, coiling, press, control, bagging and finally to the packing area; the adapters start at the wood cutting station, pipe cutting, gluing and drying, coupling, control, bagging and finally to the packing area, the last one being the common area for both unsorted products.

2.3. Diagrams of flow

The diagram describes the process that we are going to optimize and automate in chapter 3, from when the cable winches and sanding adapters are transported and stacked from the bagging area to the packaging area,

Figure 3: Winflex company flow diagram Source: Own elaboration

2.4. Diagram of analysis of process

Average times were taken for the current actions in the Winflex company, from the bagging area to before the start of packaging.

Table 1: Process analysis diagram

Source: Own elaboration

Descripción	Tiempo (mins)	SImboloía				
		●	→	⌓	■	▼
Recoger winchas del área de Embolsado	1.5					x
Llevar winchas al área de Empacado	3		x			
Recoger adaptadores del área de Embolsado	1.5					x
Llevar adaptadores al área de Empacado	3		x			
Inspeccionar piezas	12				x	
Organizar piezas en grumas del mismo producto	10	x				
Clasificar piezas en cajas	12	x				
Productos clasificados y organizados en cajas para embalar	1					x
TOTAL	44	2	2		1	3

2.5. Production indicators before automation Production

indicators:

Lead Time:

This is the amount of time that elapses from the time the work order is entered until the customer has the finished product in his hands. This allows us to record average production cycle times. This metric is fundamental to understand our production capacity and limitations and, therefore, strategic planning through measurable objectives, especially those that can be achieved in the short term.

On the other hand:

Lead Time is an expression used in the logistics world to identify the time difference in the process of a chain (Anaya, 2011).

Cost of production:

It is the most important indicator; it is essential to have a clear idea of how much we are going to invest in our project.

Production costs are characteristic of manufacturing companies, which transform raw materials with the collaboration of workers and machinery into finished products (Garcia, 2010).

Production line performance

This indicator allows to evaluate the performance of the machine when it is in production.
The most effective indicator to measure this point is the "Overall Team Effectiveness (OTE)".

Availability

It represents the percentage of time that the device is fit for use and operable. The calculation of this metric takes into account the sum of planned downtime, corresponding to routine maintenance procedures, as well as the sum of unplanned downtime, corresponding to the occurrence of unexpected events and equipment system failures. (Toro, 2018).

Performance

It quantifies the number of finished products during a time cycle produced by the machinery during a given time cycle (Corvo, 2021).
It is calculated by dividing the capacity of the machine (number of parts it can produced in a time span) between the parts it actually produced in the same time frame.

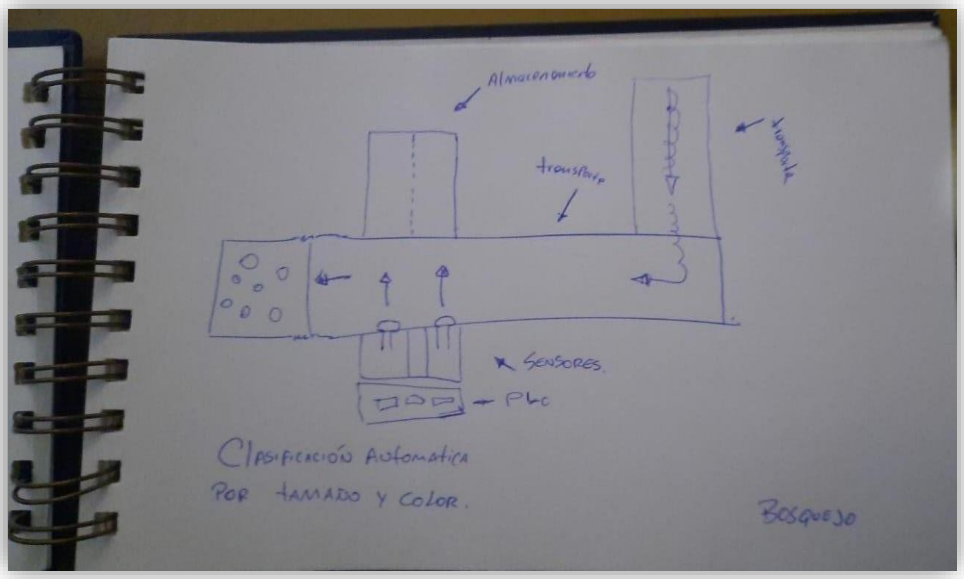
CHAPTER 3 - DESIGN PROPOSAL TO AUTOMATE THE PROJECT

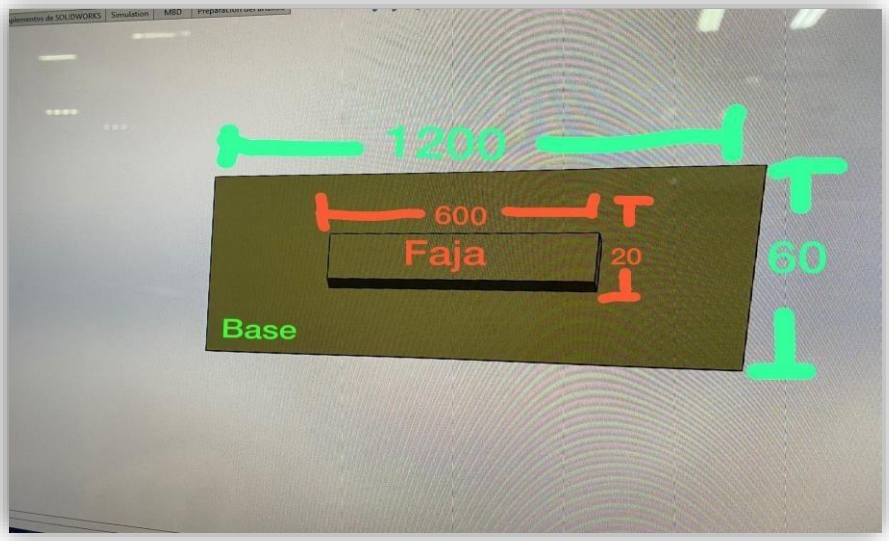
3.1. Detailed description of the proposed process

The process begins with the manual introduction of materials of various sizes on a ramp. By gravity the pieces fall to the conveyor belt, at the foot of the ramp lies a diffuse reflection proximity sensor, this sensor sends a signal to the PLC and this in turn activates the conveyor belt carrying the pieces forward, with direction to the sensor that detects the size of each piece, it will be programmed to send a signal to the PLC if it detects that the pizza has a certain height and thus activate the piston (driven by pressurized air).

The piston drives the objects into the receiving box located on the opposite side of the cylinder. Objects that are smaller than the programmed size (and therefore not detected by the sensor) pass directly to another receiving box located at the end of the conveyor. When the sensor stops detecting objects falling on the belt through the ramp, it deactivates the belt.

3.2. Project sketches





3.3. Quotation:

In this section we will see in the table below the quotation of the components required for the project.

Table 2: Component quotation table Source: Own elaboration

COTIZACIÓN			
PRODUCTO	**CANTIDAD**	**P.U**	**TOTAL**
SENSOR	2	S/ 70.00	S/ 140.00
FUENTE DE PODER	1	S/ 70.00	S/ 70.00
PISTÓN	1	S/ 70.00	S/ 70.00
ELECTROVÁLVULA 1/4	1	S/ 80.00	S/ 80.00
ELECTROVÁLVULA 1/8	1	S/ 60.00	S/ 60.00
REGULADOR	1	S/ 10.00	S/ 10.00
SILENCIADOR	2	S/ 4.00	S/ 8.00
MANGUERA	10	S/ 3.00	S/ 30.00
PLC	1	S/ 500.00	S/ 500.00
CAJA PULSADOR	1	S/ 14.00	S/ 14.00
PULSADOR ROJO	1	S/ 7.00	S/ 7.00
PULSADOR VERDE	1	S/ 7.00	S/ 7.00
PULSADOR AMARILLO	1	S/ 7.00	S/ 7.00
TOTAL			**S/ 1,003.00**

3.4. Automation plan Gantt

A Gantt chart was made with the activities performed throughout the Industrial Automation course to implement the simulation of a product sorter for the Winflex company.

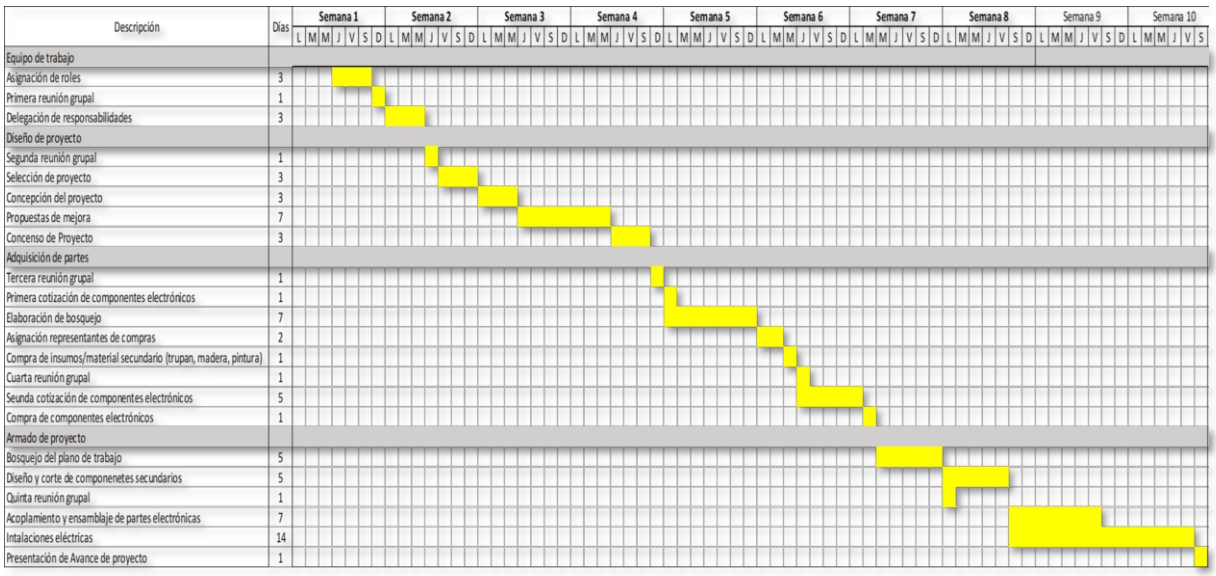


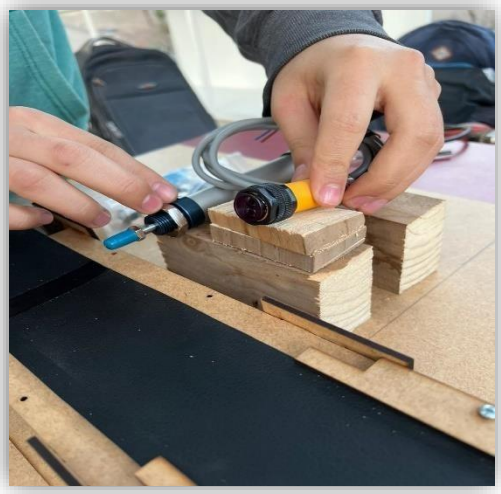
Figure 4: Gantt Chart Source:

Own elaboration

3.5. Photographic evidence

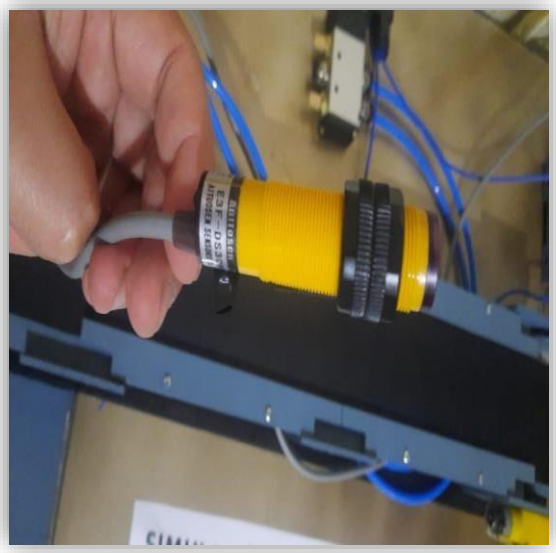
First day of meeting - Planning:

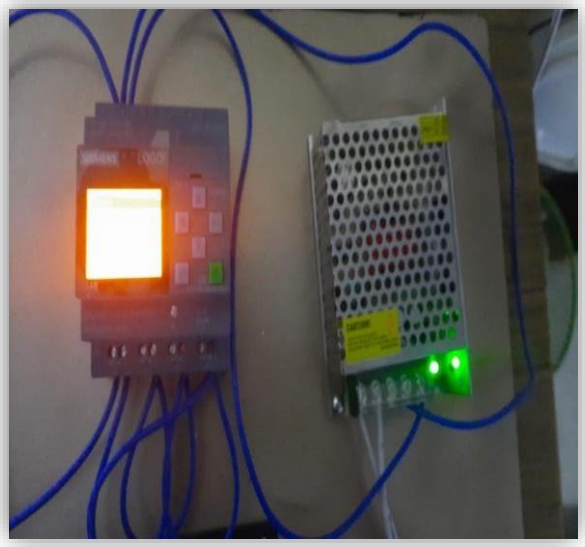
Second day of Meeting - Setting up bases and marking locations:



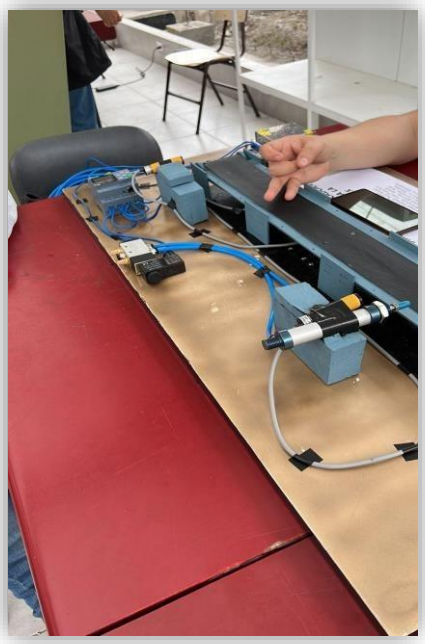
Third day of meeting - Elaboration of the aesthetic section and finalization of the assembly of components:

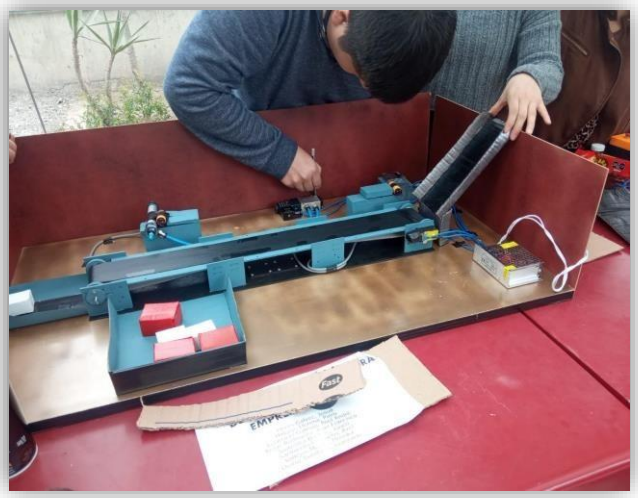
Fourth day of meeting - Electrical installations:





Fifth day of meeting - Nailing of components and finishing of aesthetics





Presentation of the finished project before the final presentation:

3.6. Proposed floor plan sketch

The proposed sketch for the implementation of the automatic conveyor belt will look as follows: it will be set up in the packaging area, automatically sorting the sandpaper adapters in box 1 and the winches in box 2.

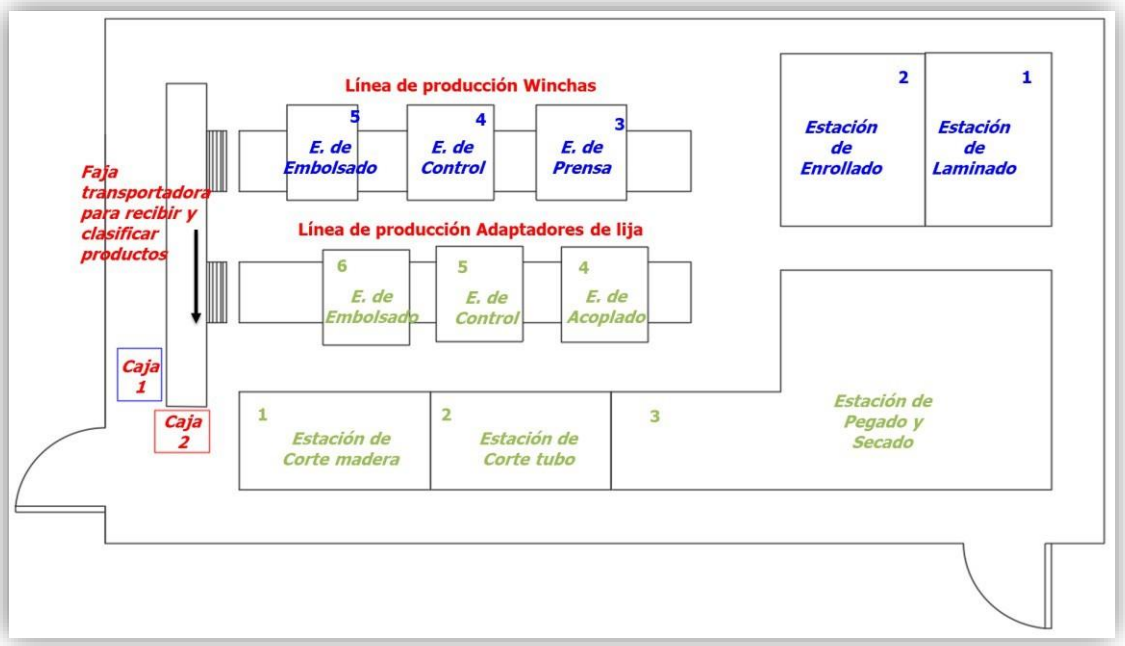


Figure 5: Proposed sketch

Source: Own elaboration

3.7. Proposed flowchart

The following flow chart is proposed as an improvement when implementing the conveyor belt in the Winflex company.

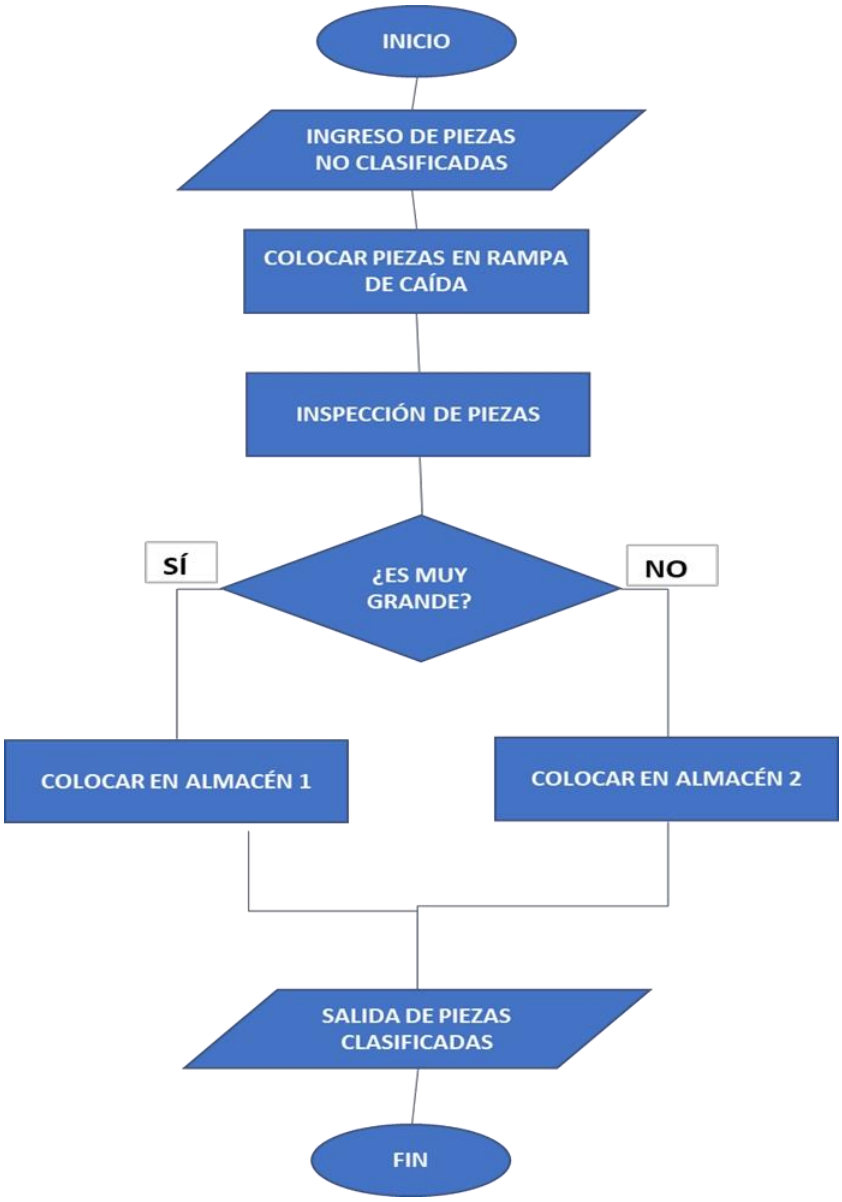


Figure 6: Proposed flow diagram

Source: Own elaboration

3.8. Detailed description of the materials to be used at .

Solenoid valves: Electro-mechanical valves, designed to regulate the flow of a fluid through a hose or conduit.

Aluminum piston: It has a cavity where pressurized air enters to drive its shaft. It has a regulator that allows controlling the expelled air pressure.

Diffuse type photoelectric sensor: It has a receiver transmitter in the same structure. It emits a signal in the direction of the objects, reflecting the light emitted to the sensor.

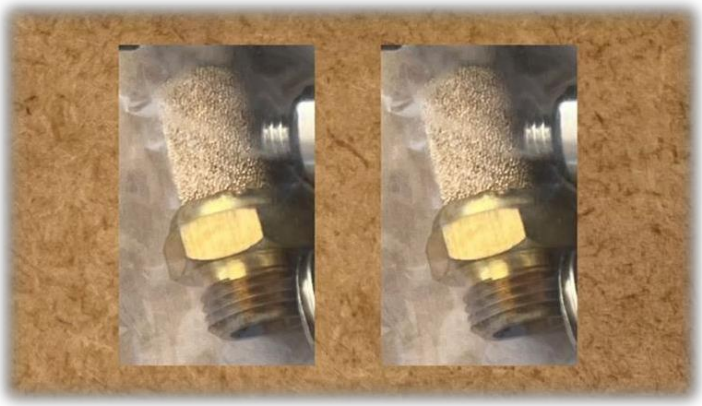
Connectors ¼": Accessory for pneumatic tools, with quick coupling end and other end with 1/4" male coupling. Hexagonal center for further tightening with wrench, if necessary.

Logo 8 12-24 Siemens: It is a computerized equipment used for the following basic automation activities. Adaptability of different projects.

Button push button: Empty box for 3-hole push button in yellow color. With reset, power on and power off functions.

6mm hose: Source of communication between the pneumatic components.

Silencers ⅛: Regulate the sound generated by the compressor pressure.



Conveyor belt: In charge of moving the material to be stored.

3.9. Circuit design electropneumatic

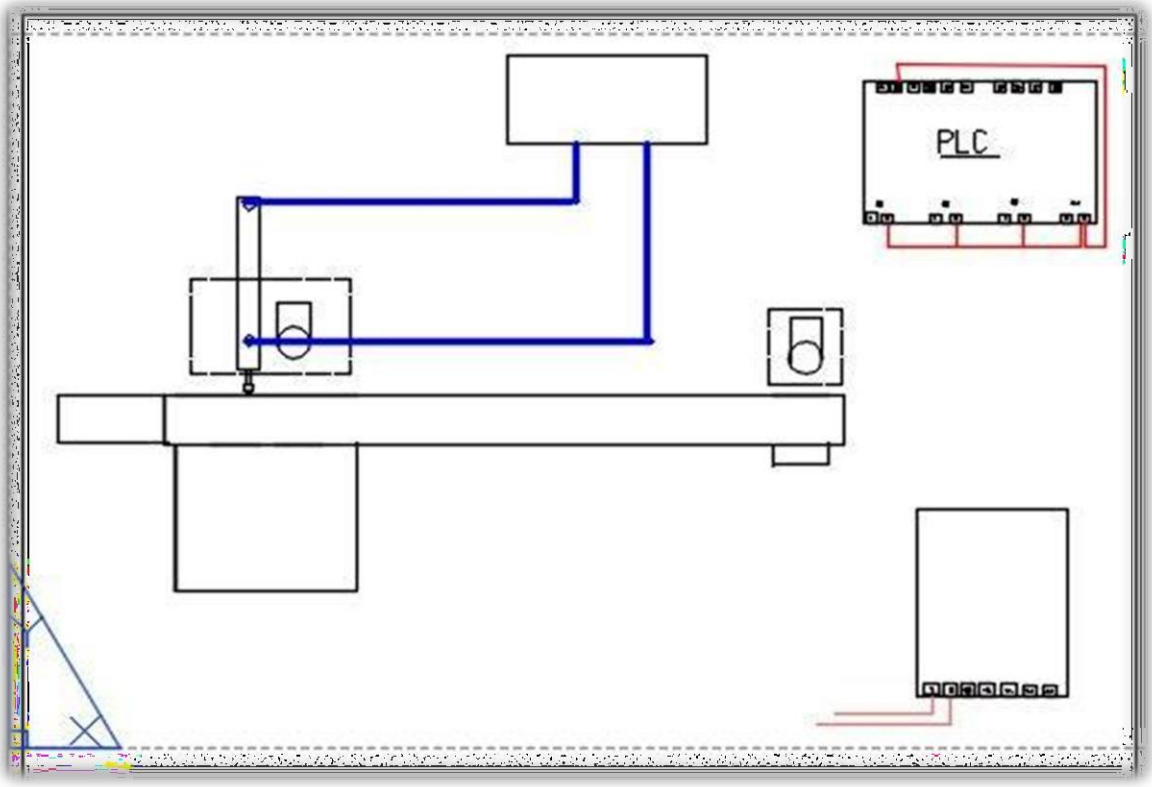


Figure 7: Circuit design Source:

Own elaboration

3.10. Programming

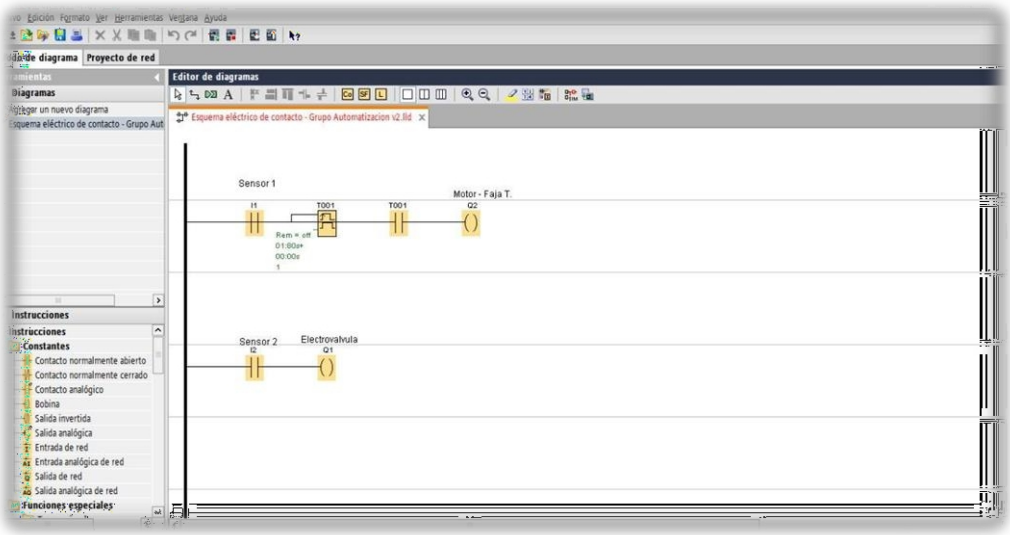


Figure 8: Programming 1

Source: Own elaboration

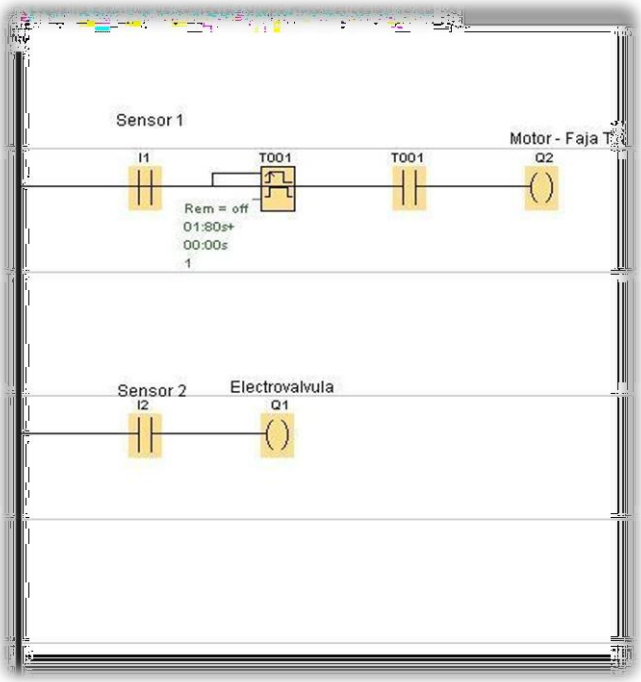


Figure 9: Programming 2

Source: Own elaboration

Description:

After feeding our **PLC** with 24V, sensor **1** turns on when it sees an object on the conveyor belt and turns on the motor so that the objects arrive, through the conveyor belt, to sensor **2** activating the cylinder **Q1** and pushing, depending if it is the required size, towards its store. But when the object is smaller, it continues its course towards the scrap store.

3.11. Production indicators after automation Manufacturing

cost:

The costs incurred in the implementation of the system in the company in the specific circumstances of the process must be considered. In this case, the cost of transportation and storage of the product within the factory is considered.

Downtime:

During production, there is downtime when no activity is performed, but electricity costs and idle operators are incurred in situations where they are relied upon.

On-time delivery:

As an automated system, there will be no delays or downtime in the process where no activity is executed, tasks are scheduled to be accurate and normal time is reduced when it is not an automated process. as a safe job.

Performance:

There are many objects that have to be moved from one point to another point further away, and the number of objects that actually have to be moved has to be taken into account in the number of objects that are actually moved.

Leveraging quality:

It is considered of better quality because there is no margin of error, there are no failures or delays, compromising the process, what can be sought is automation, at each specific time, looking for updates, reducing time, labor costs and using current in the market Modernize it with the latest technologies to monetize and better develop the project.

Competitiveness:

Labor versus automated machine counts on the ultimate improvement, in which there is improvement and certain effectiveness, as project scheduling streamlines and automates the steps.

Considerations for the operation of the project

- **Electricity**

  The voltage of electricity must be controlled before entering the system. Direct connection without a power source that reduces the amount of current should be avoided as it may burn the circuits and even cause accidents to the operator during the execution of the system.

- **Air pump**

  It must have enough air to be able to exert the pressure, not have accumulated water because it prevents its operation, be connected to the hoses of the same size, which in this case was 6mm, and have a good grip so that the work can run easily.

- **Hoses**

  The hoses must have the proper diameter to avoid accidents due to the air pressure coming from the pump. If it has a different diameter it can easily detach generating failures to the system.

- **Engine:**

  The motor must have the correct input so that it can adhere to the belt and can exercise, because the PLC is the one that transmits the signal, for the operation of the conveyor belt, as it is an automated machine has a duration time of 8 seconds if it does not fall objects that will be detected by the sensor, it will automatically shut down.

- **Sensors**

  Sensors should be placed at different heights and should not have objects too close to them that could alter their functionality. In addition, they must be securely fixed on a base.

Table 3: Indicators

Indicator	Formerly	Then
Manufacturing cost	8 soles/piece	5.2 soles/piece
Downtime x day	5 h	0.5 h
Parts stored x day (Yield)	500 u/day	30000 u/day
Incorrect parts in stock	15 u/day	0 u/day
Competitiveness	4 persons	1 machine

3.12 Industrial safety aspects after implementation of the proposed .

The system is implemented taking into account basic aspects of industrial safety, such as the use of appropriate tools for the assembly of the components, which include star screwdrivers, both large and small, and star screwdrivers for fastening to the base of the equipment. tools such as saws, etc. Medium-sized cuts are made in wood and dowels, and the wood must be secured to the work table to avoid cutting accidents during the process.

For the implementation of the electrical installation, factors such as the intensity of the current during installation are considered, since the power used by the system can reduce the possibility of accidents caused by the operator due to electric shock. In addition, we work to maintain the proper position of the operator to maintain proper ergonomics of the worker and avoid accidents due to bad posture or repetitive activities.

The system also prevents the operator from constantly moving through the system. It also prevents the operator from lifting heavy loads that could damage the operator. In addition, in the case where larger scale prototypes are used, the power supply to the system must be considered, in these cases higher voltages are required to activate the belt. Also, as the part is placed in the funnel, it must be done with another type

of the feeding system, which may require other pre- and post-operative care.

Application of engineering in design

To develop the project have been considered time and motion studies, as to perform the work has been considered a bimanual map to understand what movement is required before assembling the system, and to understand the time required to complete it. without an automated system. On simulating the transport of elements of any large object such as a box or package, and the basic electrical principles of installing wiring and equipment in the system to properly operate the mechanics of a piston pushed by air through a solenoid valve. In addition to applying software such as SolidWorks to detail the structure and AutoCAD, visualization of the electrical connections and valves that drive the air to the pistons.

Industry applications

As potential clients to apply our project on a larger scale we have:

- **Bottling companies:**
  By having an automated system that selects objects according to their size, it can adapt to different sizes such as large, medium and small bottles existing in the market, whether in bottles of beverages such as soft drinks, beer, wine or other liquors and even canned beverages.

- **Metal parts production companies:**
  In metal-mechanical companies often require the separation of several pieces for effective work that continuously need to make repetitive movements and which in turn can cause damage to the operator as injuries or accidents. With the implementation of the project could reduce manual repetitive work by an operation and reducing the likelihood of accidents which would only happen to control the same machine or could control other equipment generating higher performance to the company.

- **Processed food industry:**

  Food industries need to process some products by putting them in cans for a long shelf life and to avoid contamination. In the market there are several brands that use cans for preservation as in the case of seafood such as tuna and shellfish or also in the case of processed fruits and vegetables such as artichokes, peaches and beans which require containers of different sizes to be selected for storage and / or transport.

  The implementation of an automatic sorting system would reduce sorting time and provide adequate storage that is appropriate to the type of product that needs to be stored or sorted for subsequent distribution to stores or supermarkets.

- **Mining industry:**

  In the mining industry there are operations that require the selection of materials according to their size as in the case of mineral fragments that are extracted and need to be separated for treatment, often this process is done manually and takes a long time or even inadequately generating reprocesses.

  With the implementation of our prototype the working time can be reduced and a proper separation can be guaranteed reducing accidents during the extraction of minerals.

- **Manufacturing industry:**

  Manufacturing companies need to streamline their movements to reduce operation time, which is why they often automate some movements with transportation. In this particular case, the conveyor belt could be used to carry the objects from one point to another in which the selection can be made in different sizes, whether boxes or containers, which in the case of fragile products can be adapted to different shapes so that they are not damaged or hit hard.

CHAPTER 4 - BENEFITS

The benefits to be gained by implementing an automatic classification system would be:

- **Minimize operation times:**

  With the implementation of any system, the aim is to reduce operation times in industries in order to optimize processes, which leads to consequences such as streamlining the process and reducing work time.

- **Reduce energy costs:**

  An automated system also reduces energy costs, in our case we expect the reduction of electrical energy by having a sensor that controls the movement of the belt and when it stops detecting objects, it stops the movement of the belt by sending a signal to the PLC that orders the motor to stop until a new operation, thus preventing the motor from consuming electrical energy constantly and doing it rather intermittently according to the action of the operator who controls the system.

- **Automated operations:**

  Automated operations contribute to streamline processes as in the case of repetitive processes in which they can be done faster, sometimes even without constant supervision. It is important this point because when there are automated operations can work up to full days of even 24 hours in which no lighting is required on the premises during the night.

- **Accuracy in operations:**

  Certain operations require precision in their movements as in the separation of objects to be stored, for example, in logistics companies agility of operators is required to select a product and place it in another, but that requires movements that often become repetitive generating accidents in operators. This problem can be solved with the implementation of an automated system.

- **Reduction of occupational accidents:**

  Occupational accidents within companies can occur for various reasons. In the case of manufacturing or logistics companies, overconfidence can appear among operators who already know the movements perfectly well and who in the long run tend to commit overconfidence in the knowledge of an operation, which generally leads to accidents. It is because of this problem that automation systems can be implemented to help minimize accidents due to interaction with industrial equipment such as conveyor belts or accidents due to lack of proper ergonomics such as lifting and transporting many heavy loads such as blocks, bags or boxes.

- **Reduced labor costs:**

  With the implementation of this kind of systems, the number of people during the processes can be reduced from the need of 5 or 4 operators to only 1 operator or sometimes even eliminate them, thus eliminating the cost in payments to operators, generating savings in the companies and also speeding up the movement time. For example, in airports several operators are required to separate the suitcases before placing them on the plane, these operators are usually in the path of the belt accommodating according to their size. With the application of this system, the number of operators can be reduced to a maximum of only 2 or 3. This situation is something that has been happening a lot in countries that are world leaders in the manufacturing industry.

- **Injury reduction:**

  With the implementation of the automation system, human interaction with the objects is reduced, thus avoiding injuries in the company's workers, in addition to the reduction of injuries in the absence of personnel due to minor or probably serious injuries, for example, workers will no longer have back injuries due to maneuvering objects, injuries in the transport of objects due to falls.

CHAPTER 5 - CONCLUSIONS

- We can conclude that, automation systems suggest several general factors to take into account before starting any project, a detailed description of the whole system to be automated is required to see the results.

- It is very important for a company to thoroughly analyze its process, as there are many factors at play. Failure to take these factors into account can lead to quality problems, financial losses and production losses, putting products, customers and the company at risk.

- It is also concluded that the implementation of an automated classification system helps to solve various problems in different areas of engineering, streamlining operations and reducing operating costs during the development of processes or even in logistics areas for efficient performance. In addition to collaborating with safety within companies as they reduce the exposure time to equipment that can cause accidents either mechanical or electrical.

- The design and development of an automatic classification system generates a reduction in occupational accidents, injuries and personnel shortages, thus increasing the safety of the processes in the facilities of the company that implements this system.

CHAPTER 6 - RECOMMENDATIONS

- Evaluate which processes can be automated and produce better performance.

- Analyze what type of technology can be applied in automation.

- Help in the automation of human teams, these processes are intended to improve efficiency and profitability.

- We must always look for options for continuous improvement, seek and analyze solutions that provide value.

CHAPTER 7 - BIBLIOGRAPHY

CUBAS, A., Margarita, L., Valdizán, A., & Thalia, I. (2018). ""Lead time" and its influence on the service level of express delivery service companies for U.S. imports". Presented at the Universidad Peruana de Ciencias Aplicadas (UPC), Lima, Peru. http://hdl.handle.net/10757/623786.

MICHUE García, Ramón, Contabilidad Analítica de Costos, first edition 2010, Lima Perú.

TORO, R. (December 12, 2018). *Fractal*. Retrieved from: https://www.fracttal.com/es/blog/disponibilidad-indicadores-gestion-mantenimiento

CORVO, Helmut (April 15, 2021). Production indicators. Lifeder. Retrieved from https://www.lifeder.com/indicadores-produccion/

GARCÍA, Emilio. Automation of industrial processes. Mexico, Alfaomega Grupo Editor, 2002.

NIEBEL, Freivalds. Industrial Engineering. Methods, Standards and Work Design. Mexico, Alfaomega Grupo Editor, 2001.

HARRINGTON, James. Business Process Improvement. Colombia. McGraw-Hill, 1994.

CHASE, Richard B. Production and operations management in manufacturing and services. Bogotá, McGraw-Hill, 2003.

BALLOU, Ronald. Logistics Supply Chain Management. Mexico, Pearson education, 2004.

BLANCO, Luis Ernesto. Simulation with Promodel: Production and Logistics Cases. Colombian School of Engineering, 2001.

KONZ, S. Diseño de Instalaciones Industriales, Limusa, Mexico, 2000 MAYNARD, Harold. Industrial Engineer's Handbook. Editorial McGraw Hill. Mexico, 1996.

HWANG, Hark, MOON Seongwoo and MITSUO Gen. An integrated model for the design of end of aisle order picking system and the determination of unit load sizes of AGVs. In: Computer and industrial engineering. Vol 42; 2002.

CHAVEZ, Fabian. Design of an automated machine for the classification of chicken prey. Universidad Autónoma de Occidente. 2014

NAHMIAS, Steven. Production and operations analysis. Mc. Graw Hill. Mexico, 2007. LADOU, Joseph: Medicina laboral y ambiental. Mexico. Manual Moderno, 1999.

CABALLERO, José Orlando. Industrial Automation. Laboratory practice manual. Bogotá: Editorial Pontificia Universidad Javeriana: 2008. HORTA, José. Industrial automation techniques. Mexico: Editorial Limusa. 1982.

MARTINEZ, Jose . (2015). Proposal for automation of a final process automotive gears Mg thesis in advanced manufacturing.

CORDOVA, E. (2006). Manufacturing and Automation. Engineering and Research. Vol. 26.

FUSTAMANTE, Wilmer. Design of an automated onion grading machine by size and color. Señor de Sipán University. 2018.

CAJAMARCA U. Jorge Leonardo. Design and Simulation of a sorting and counting machine for tree tomatoes. Salesian Polytechnic University of Cuenca. 2021.