UNIVERSIDAD RICARDO PALMA

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PROFESSIONAL SCHOOL OF INDUSTRIAL ENGINEERING

INDUSTRIAL AUTOMATION

RESEARCH WORK

"Design and implementation of a sorting machine for metal, plastic and paper waste to promote recycling in Lima."

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INTRODUCTION

"You must make recycling become a way of life."

-Mario Vargas Llosa

In this research project, we present a project that aims to teach and disseminate the correct way to recycle waste. However, in our country there are enormous opportunities to increase recycling, since only 1.9% of the total solid waste generated is recycled, which can be used in different ways.

Today, recycling is a global necessity not only to improve the quality of the environment, but also to protect human health. In addition to employment, recycling paper, plastic, glass and metals, among other things, saves raw materials extracted from nature and thus extends the life of landfills in our cities, where every day there is less space for solid waste, requiring the introduction of new processing technologies and proper waste management.

On the other hand, we will touch important points for the quotation of the materials to be used and the most feasible ways where we made the acquisition of these, after defining and knowing the functions of each piece to be used, we will make a sketch where we will have a preview and an important guide to start our work.

1. PROBLEM STATEMENT

1.1. Determination of the problem

The reality facing public health in the country is the weak management of solid waste. Questions such as: Who is in charge of ensuring that the waste reaches a correct destination, where does the solid waste that we generate every day go?
What should we as citizens do to improve the situation? Those questions at first glance have coherent answers, but in reality, the most coherent answers are often unsolvable riddles.

In 2020, MINAM (Ministry of the Environment) reported that almost 8 million tons of solid waste were produced in Peru. It should be noted that there are two types of MSW: non-municipal waste and municipal waste. Of the 76.4% made up of usable organic and inorganic waste, only 0.98% is recovered, equivalent to 59021 tons. With respect to the above information, only the indicators show an existing problem with solid waste management.

Figure 01: Composition of solid waste generated in 2020 (million tons) Source: ComexPeru

However, according to the Integrated Solid Waste Management Law, the collection, treatment, transportation and/or recycling, and safe final disposal of common solid waste is the responsibility of these entities. Likewise, at the provincial level, they must implement a PIGARS (Plan Integral de Gestión Ambiental de Residuos Sólidos), while at the district level, it is suggested to have a PMRS (Plan de Manejo de Residuos Sólidos). Ergo, what was planned is not actually being implemented.

In 2020, according to the National Registry of Municipalities, 11.9% of municipalities nationwide do not have any solid waste management instrument and only 55% of them have a Solid Waste Management Plan. Of the 1844 municipalities that provide waste collection services, 84% deposit it in a landfill, 31.2% send it for recycling, 18.3% send it to sanitary landfills, 10.1% incinerate it and the remaining 5.9% is used for composting. This is worrisome, considering that landfills are illegal by law.

This would explain why we lack adequate infrastructure for waste management, which in turn creates poorly managed landfills and represents a serious risk to the environment and the health of citizens. To have a panoramic view of what is happening, according to Minam, at a national level, of the 64 sanitary landfills, only 210 of the 1874 districts are covered. And to make matters worse, Arequipa, Madre de Dios and Tacna do not have one this year.

The consequences that this situation generates, not only go from environmental problems, but also health problems for citizens who every day must live with foul odors and an unpleasant view for anyone. What does our government, municipality to improve this situation? However, not all the problem comes from the big authorities, but from us as citizens, what should we do to help improve the situation?

1.2. Problem formulation

1.2.1. General problem

How to design and implement a sorting machine for metal, plastic and organic waste to promote recycling in Santiago de Surco?

1.2.2. Specific problems

a. How to implement the mechanical structure of a sorting machine for metal, plastic and organic waste to promote recycling in Santiago de Surco?

b. How to code a program in LOGO software connected to a PLC to recognize waste of metal, plastic and organic origin by using sensors?
c. How to increase the volumes of recycled materials with automated prototypes that identify materials by their characteristics in Santiago de Surco?

1.3. Importance of the research work

The following research work is proposed focusing mainly on making people aware of the importance of recycling. In addition to promoting the use of knowledge about automation in order to create a viable project for the environment. In this way, the amount of solid waste found daily in our environment would be reduced.

1.4. Justification of the research work

1.4.1. Theoretical justification

It is justified theoretically, in reason to use the scientific theoretical inquiry on concepts of automation and programming in PLC. In this way, we have an effective way for the design and construction of the project. Among the main concepts to review, we have the sensors, which will allow us to recognize the materials to be classified in the machine, we also have the concept of PLC, being a fundamental part in the operation of the prototype. On the other hand, we must not forget those concepts of electricity and manufacturing.

1.4.2. Practical justification

It is proposed to implement concepts such as electricity, automation and PLC programming, to contribute to the design and development of the prototype. In this way we seek to increase and strengthen our acquired knowledge from past cycles.

1.4.3. Social justification

It is socially justified, in order to apply social scientific research in relation to the use of automation, electricity and programming tools. At the same time, it seeks to establish a habit towards students, parents and all people about the importance of recycling and in a didactic way through the project represent the correct way to recycle.

1.4.4. Economic justification

It is proposed to implement concepts such as electricity, automation and PLC programming to improve people's recycling habits. If the project is applied on a large scale, it will represent a saving in the maintenance of the silos where solid waste from the entire city is deposited. In addition, all correctly sorted waste will be implemented in production processes of new products, thus presenting considerable savings in the use of materials that can be obtained in those sorted waste.

1.5. Objectives

1.5.1. General Objective

Design and implement a sorting machine for metal, plastic and organic waste to promote recycling in Santiago de Surco.

1.5.2. Specific objectives

a. Implement the mechanical structure of a sorting machine for metal, plastic and organic waste to promote recycling in Santiago de Surco.
b. To code a program in LOGO software connected to a PLC to recognize waste of metallic, plastic and organic origin through the use of sensors.
c. Increase the volumes of recycled materials with automated prototypes that identify materials by their characteristics in Santiago de Surco.

2. THEORETICAL FRAMEWORK

2.1. Theoretical basis

2.1.1. Automation

Automation is the correct implementation of technological improvements in certain repetitive production processes, thus achieving greater efficiency and effectiveness for the benefit of productivity.

2.1.2. Environmental impact

According to Alex Pascual (2016), it is referred to as, "It sheds some light on the world of waste and its recycling." (p.14). Reflection on waste management, giving us to understand that environmental impact is the alteration of the environment by certain actions carried out by mankind. Every action carried out by man influences and affects the environment in some way, and we have the solution to take care of it.

2.1.3. Innovation

From the point of view of Robbins, S. (2018), he defines innovation to "a way of exploring, taking risks and doing things differently, in that way we achieve an improvement of themselves, as well as the creation and implementation of completely new elements is also possible." (p.16)

According to Hidalgo (2011), he reveals that innovation is a strategic vector that "allows the company to improve its competitive position, in this sense, organizations should incorporate within their strategy actions aimed at managing innovation techniques, with the purpose of acquiring adaptability in the improvement of processes". (p. 99)

2.1.4. Ranking

According to Pablo Gonzales Casanova (1996), he tells us "classifications are like snapshots that fix genres and differences, orders and hierarchies" (p...). (p...) Classification is the action or process of organizing and separating according to certain criteria in common of certain elements that have a characteristic in common to form specific groups.

2.1.5. Programmable Logic Controller - PLC

PLCs are programmable logic controllers, which are programmed and configured according to the necessary requirements by means of a program. They are also considered as the "brain" since the correct operation of the process depends on it.

Pablo A. Daneri (2008) refers to it as "an electronic equipment, programmable by the user in non-computer language, and which is intended to govern, within an industrial environment, machines or logical and/or sequential processes" (p.15). This definition refers to the fact that the PLC will be the brain of an automated system for the control of machinery in an industry.

2.1.6. Sensors

A sensor is any sensor that has a property that is sensitive to a certain stimulus or environment. Currently, there are different types of sensors, the best known being proximity, magnetic, temperature, sound, etc. sensors.

For the concept, Probert (2001) refers to it as "In the concept the sensor consists of two parts: a transducer to produce wave energy, and an aperture or antenna to radiate or receive such energy. How-ever these may be integrated into a single component" (p. 24).

In addition, it is known that they are currently used to capture physical magnitudes and convert them into measurable analog voltage giving them an output by different systems, in addition to the changes or variations that can detect are light, temperature, distance and other changes in the environment.

2.1.7. Programming

Programming is a process in which instructions are created in a certain programming language that will indicate the correct execution of some kind of task that a software or machine.

Now, according to Juganaru Mathieu, M. (2015), the definition of programming puts it as follows:

In order to execute what the user wants to do on his computer, or to solve a specific problem, he needs to find software that performs or executes exactly the task he has set himself, or to design and develop (write) a program that performs it. The work of developing a program is called "programming". But programming is not only the work of writing the code, but a whole set of tasks that must be accomplished, so that the code that was written is correct and robust, and fulfills the goal or goals for which it was created. (p. 15)

With respect to the above, we can extract the sentence that the work that generates a program, takes as a name, programming. This is curious, since in some places, the concept of programming is merely an action of controlling a program.

However, Pinto, M. S. M., Monteiro, A. F., & Osório, A. J. M. (2022), the importance of programming lies not only in helping us to solve mishaps with respect to the computational domain, but also in the following way:

Today, programming is considered a new literacy, essential to meet the demands of an increasingly digital society, constantly changing and adapting. Programming surrounds the development of skills associated with computational thinking, such as problem solving or logical reasoning. From this perspective, learning to program includes transversal skills, with the interest of forming active citizens, with a critical and creative spirit and autonomy (2nd paragraph).

2.1.8. Relays

A relay is an electromagnetic device which performs the function of a switch that will allow the passage of electric current through its components, either to open or close circuits, which will be operated electrically and not manually.

Agapito Mendoza Romero (2010) defines that "a relay can be represented by a coil and a contact; the coil receives the current or potential signal from the system and the contact, in case of failure, sends the trip signal to the corresponding switch" (p 14). The relays work with a coil creating a magnetic field, which will allow moving circuits to change the position of the contacts.

2.1.9. Actuators

It is a device manufactured to transform energy; which by receiving a signal has the function of generating a force on a mechanism connected to the actuator.

Leonel G. Corono Ramírez, Griselda S. Abarca Jiménez, Jesús Mares Carreño (2014) define an actuator as "a device with the ability to generate a force that exerts a change of position, velocity or state of some kind on a mechanical element, from the transformation of energy"(p. 25). Currently there are several types of actuators with the purpose of automating processes to generate greater productivity in industries.

2.2. Background

2.2.1. Background 1

Project developed by students of the School of Engineering of Antioquia.

The first project developed by students of the School of Engineering of Antioquia in 2013, the name of the project is "Solid Waste Separator". The model has a single ramp which guides the materials introduced to one of the three gates that operate independently. These three gates are intended for the correct storage of the first compartment for objects compatible with the description of a plastic, the second compartment for objects compatible with the description of an organic object, the third compartment for objects compatible with the description of a metal.

2.2.2. Background 2

Logically controlled sensor detection device for the separation of paper, plastics, glass and metals.

Bruno, one of the managers of this project, describes it as a "detection device using logically controlled sensors for the separation of paper, plastics, glass and metals". First they present the materials and devices with which the project is conformed.

- Inductive sensor
- Capacitive sensor
- Optical sensor
- PVC pipe
- Arduino functional system

The difference with the first antecedent is that this one uses a PVC pipe to transport the materials working as a first ramp to then fall into a second ramp. The first gate opens upon detection of an object compatible with the description of a metal, the second gate opens upon detection of an object compatible with the description of an organic object, the third gate opens upon detection of an object compatible with the description of a plastic.

2.2.3. Background 3

Project elaborated with capacitive and inductive sensors ft. Arduino.

The third antecedent is a project carried out by students of the IDAT institute in Peru in 2018. This system has a similar operation to those seen previously. It has capacitive and inductive sensors, which were programmed with a programmed Arduino controller. The first gate is activated when an object compatible with the description of a paper is detected. The second gate is activated when an object compatible with the description of a plastic is detected. The third gate is activated when an object compatible with the description of a metal is detected.

2.3. Components

2.3.1. 24v motors

It is a direct current electric motor, in which its operation is at 24 volts.

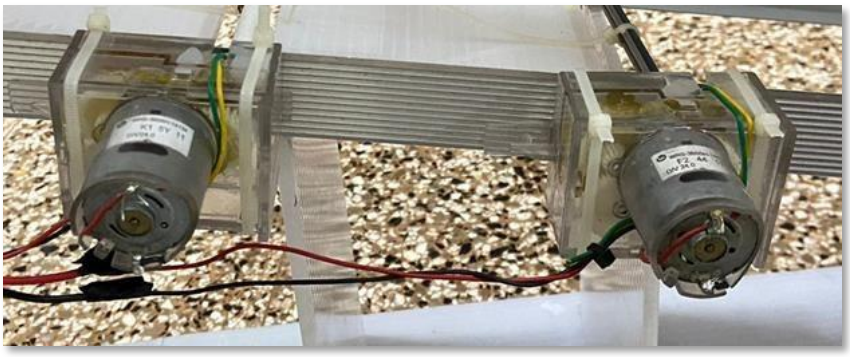

Figure 02: 24 volt motor Source:
Own elaboration

2.3.2. Relay with Base

The relay or also known as Relay is an electromagnetic device that functions as a switch by which a coil and an electromagnet is actuated thus allowing to open or close other independent electrical circuits.

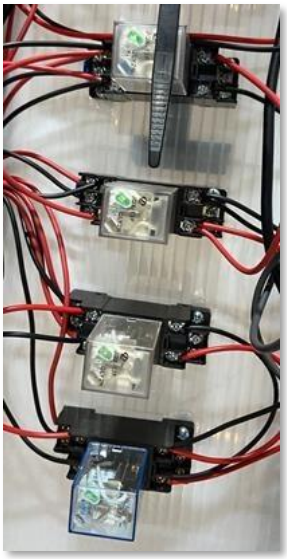

Figure 03: Relay
Source: Own elaboration

2.3.3. 220v to 24v power supply

It is a device that is used as a voltage source, has two terminals responsible for generating the output voltage regardless of the loads that can receive thus providing energy.

Figure 04: 220 volt source Source:
Own elaboration

2.3.4. 3-wire inductive sensor type PNP

It is a type of electrical sensor in charge of determining ferrous elements at a certain distance.

Figure 05: Inductive Sensor
Source: Own elaboration

2.3.5. 3-wire capacitive sensor type PNP

It is a type of electrical sensor responsible for determining any type of material, whether ferrous or non-ferrous, at a certain distance.

Figure 06: Capacitive sensor
Source: Own elaboration

2.3.6. PLC Logo 8 - No display

PLCs are programmable logic controllers, which are programmed and configured according to the necessary requirements by means of a program. They are also considered as the "brain" since the correct operation of the process depends on it.

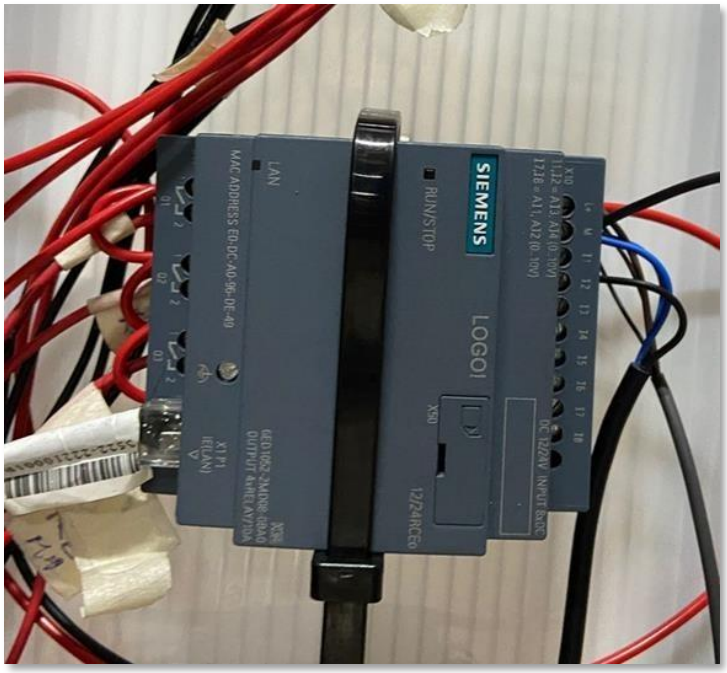

Figure 07: PLC Logo
Source: Own elaboration

2.4. Flowchart

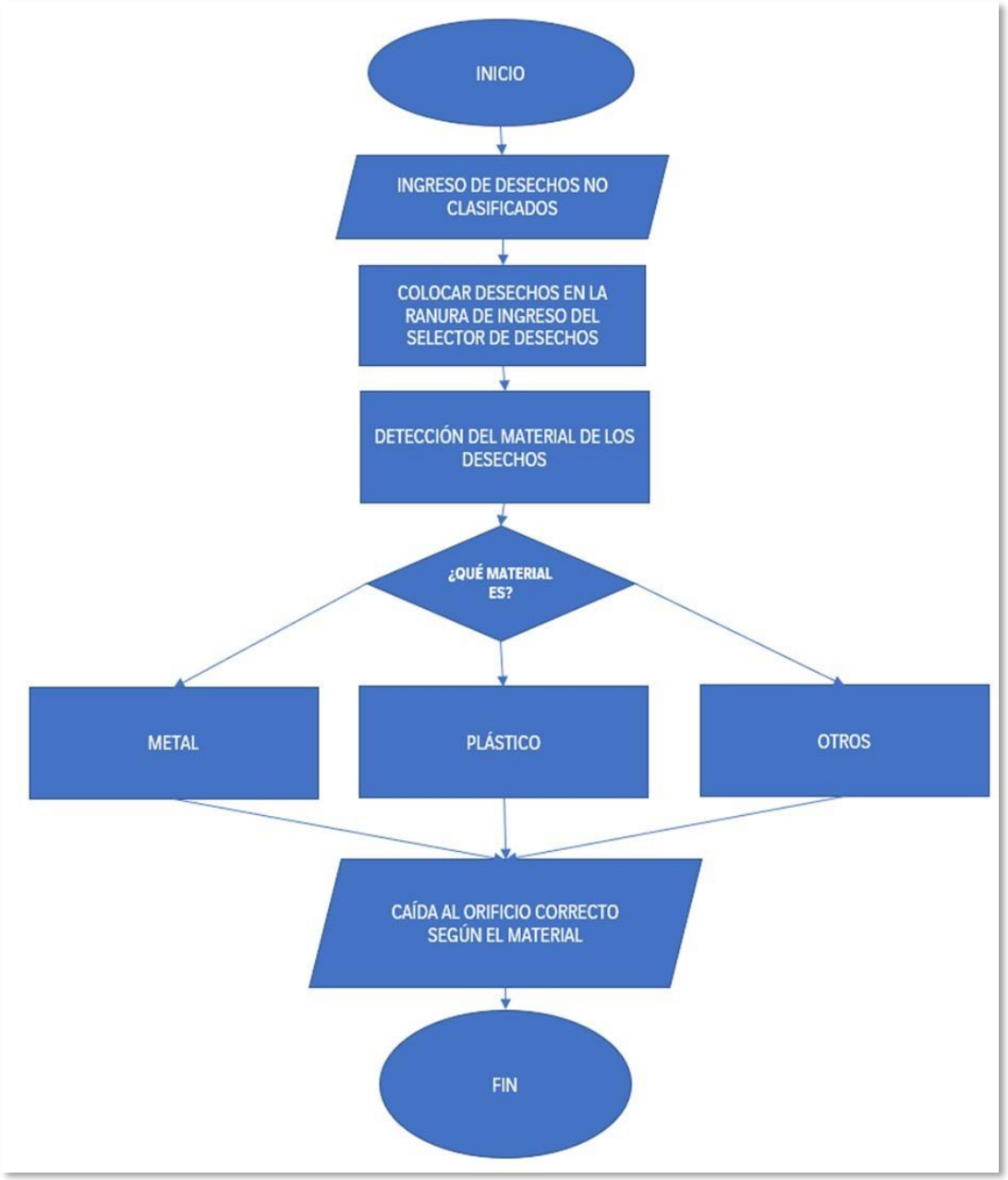

Figure 08: Flow Diagram Source:
Own elaboration

2.5. Processing steps

2.5.1. Phase 1: Planning

- Group concentration
- Determination of objectives
- Definition of requirements
- Elaboration of designs
- Design approval
- Acceptance of content
- Project confirmation

2.5.2. Phase 2: Development

- General architecture
- Definition
- Quotation of components
- Purchase of components
- Structure assembly
- Installation of the components in the structure
- Project wiring
- PLC programming

2.5.3. Phase 3: Launching

- Automated system testing
- Exhibition

3. STRUCTURE DESIGN IN SOLIDWORKS

3.1. 3D design of the project structure and components

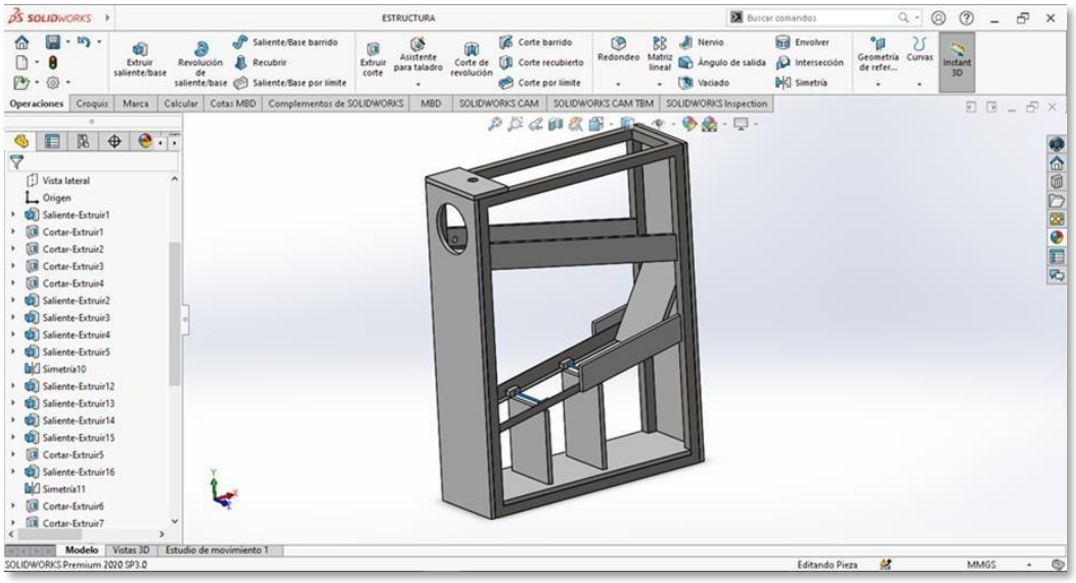

Figure 09: Project structure - Solidworks (View 1) Source:
Own elaboration

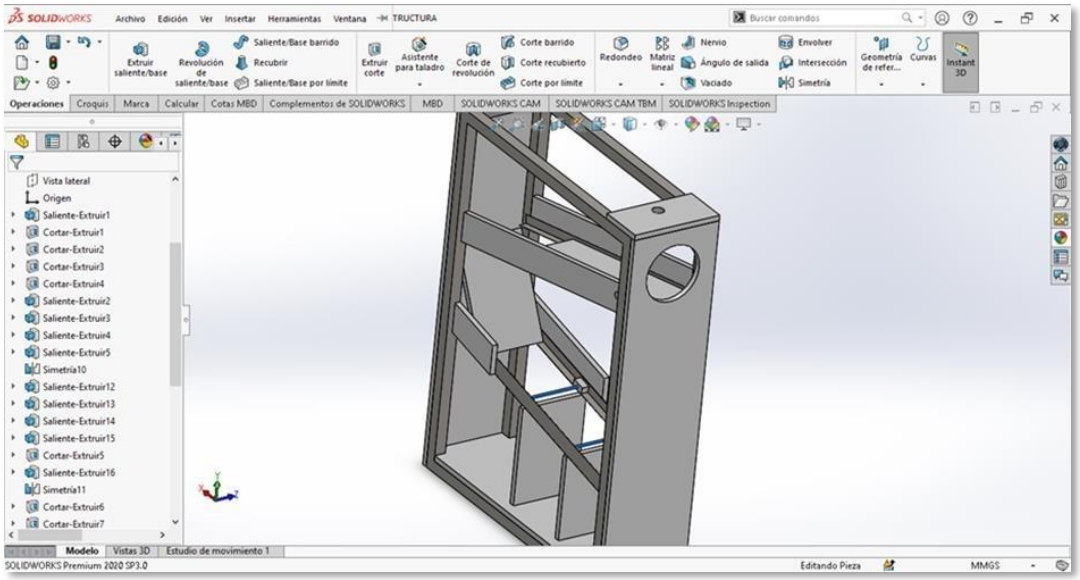

Figure 10: Project structure - Solidworks (View 2) Source:
Own elaboration

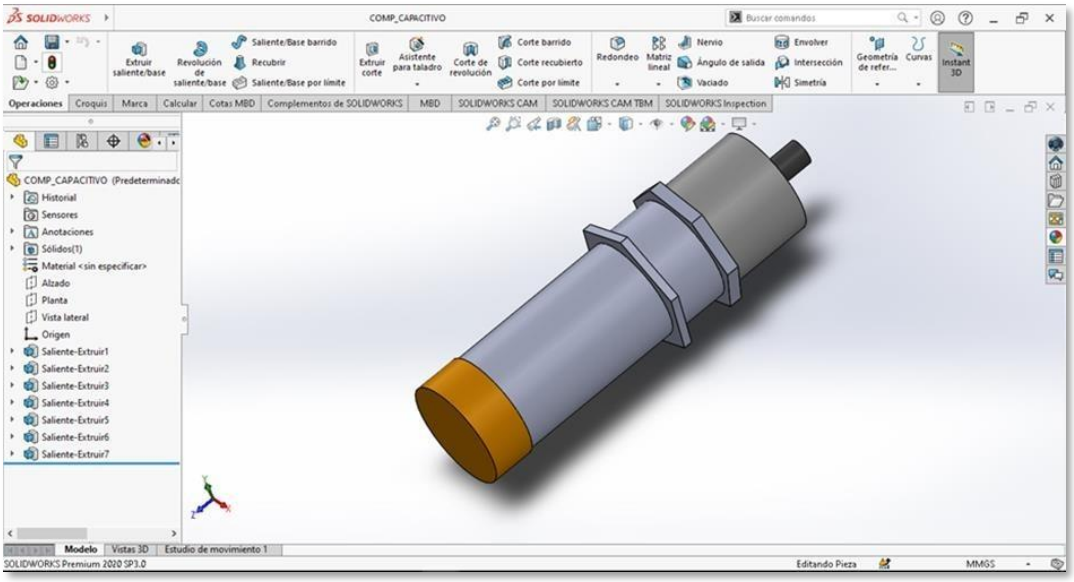

Figure 11: Capacitive sensor - Solidworks
Source: Own elaboration

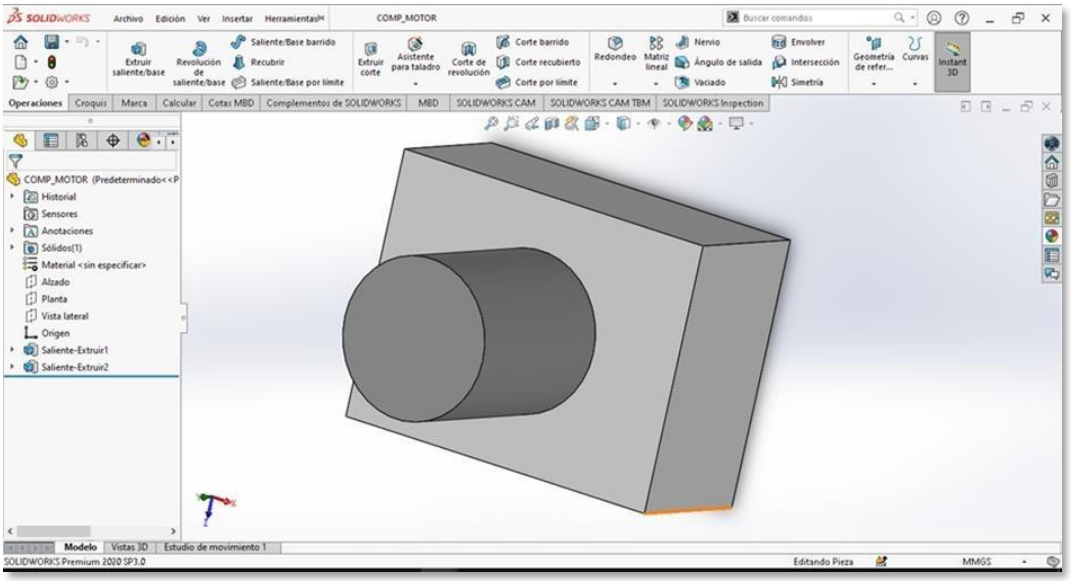

Figure 12: 24v motor - Solidworks
Source: Own elaboration

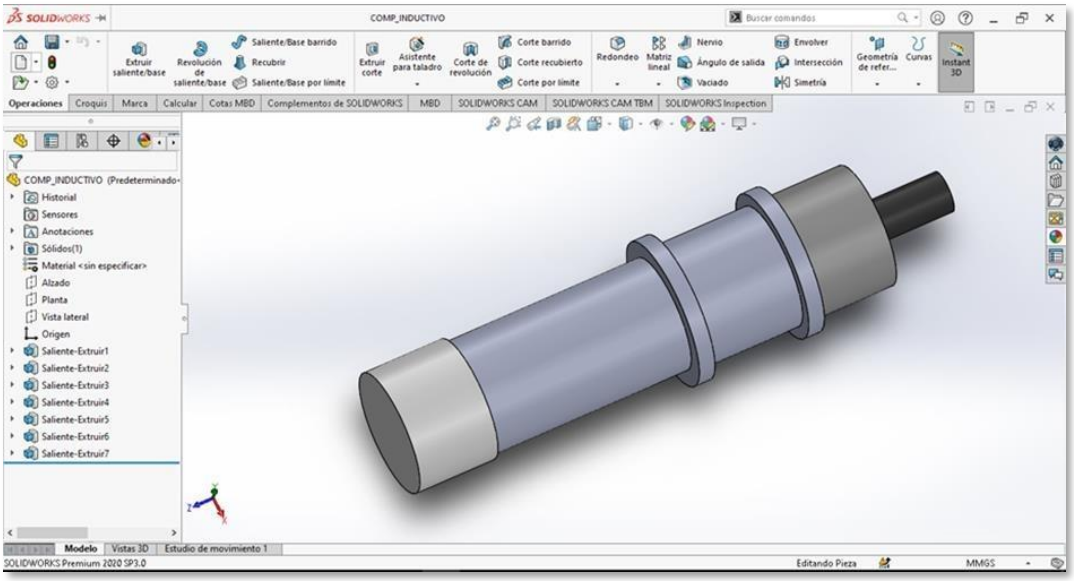

Figure 13: Inductive sensor - Solidworks
Source: Own elaboration

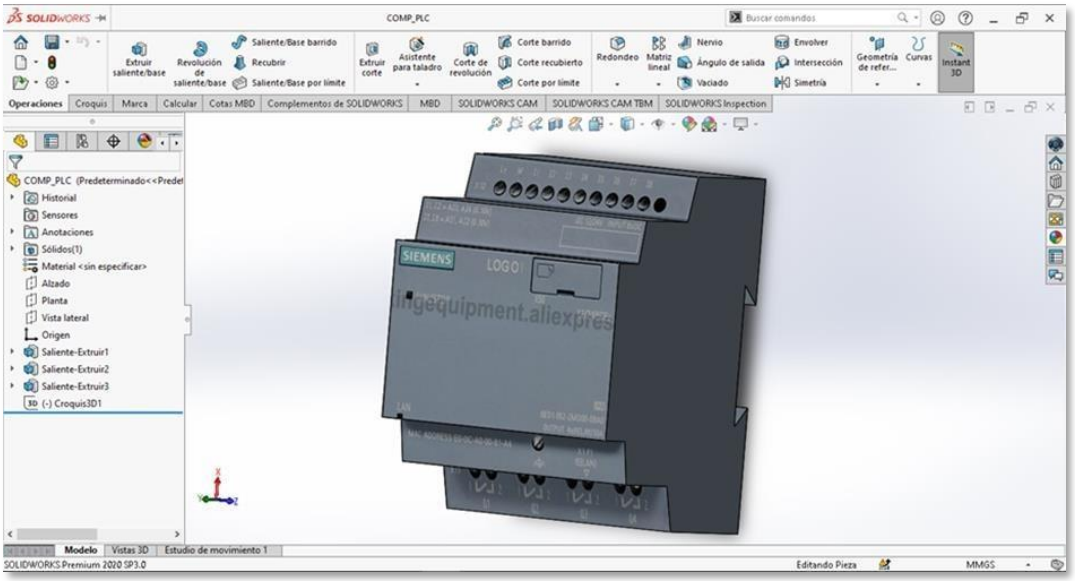

Figure 14: PLC - Solidworks
Source: Own elaboration

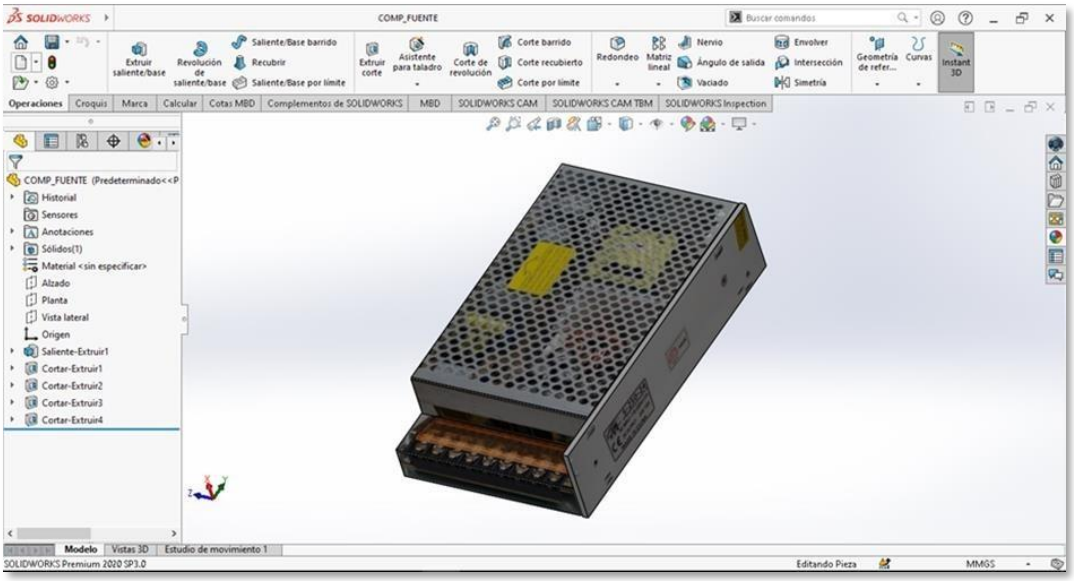

Figure 15: Power supply - Solidworks Source:
Own elaboration

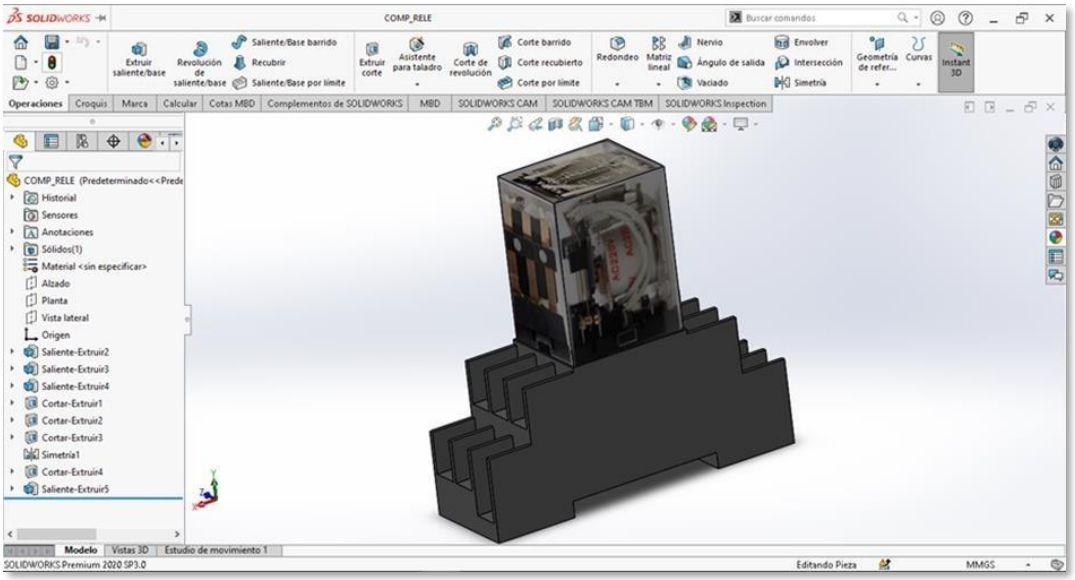

Figure 16: Relay - Solidworks
Source: Own elaboration

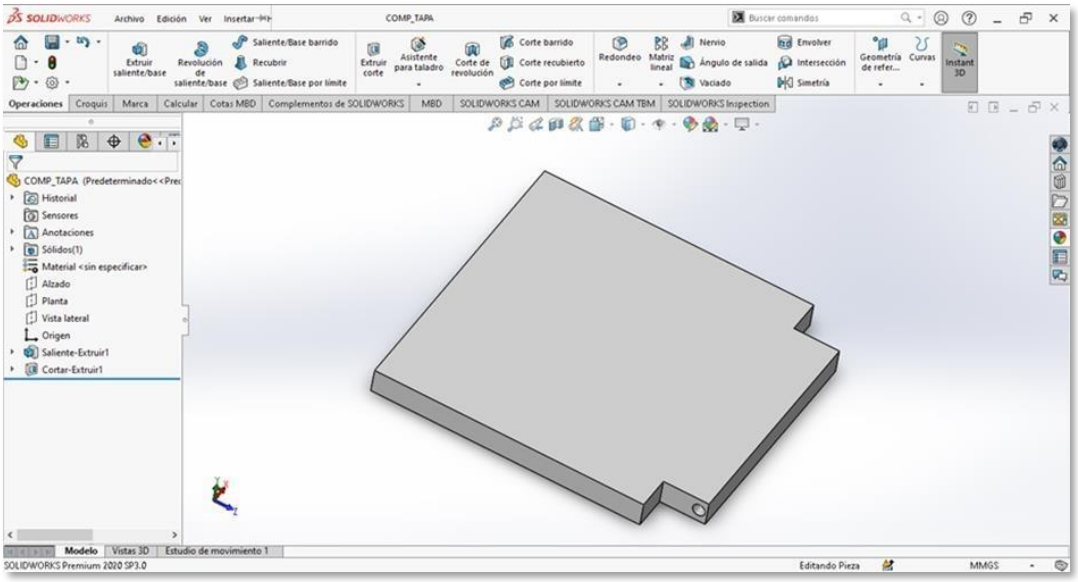

Figure 17: Structure cover - Solidworks Source:
Own elaboration

3.2. 3D design of the assembled prototype

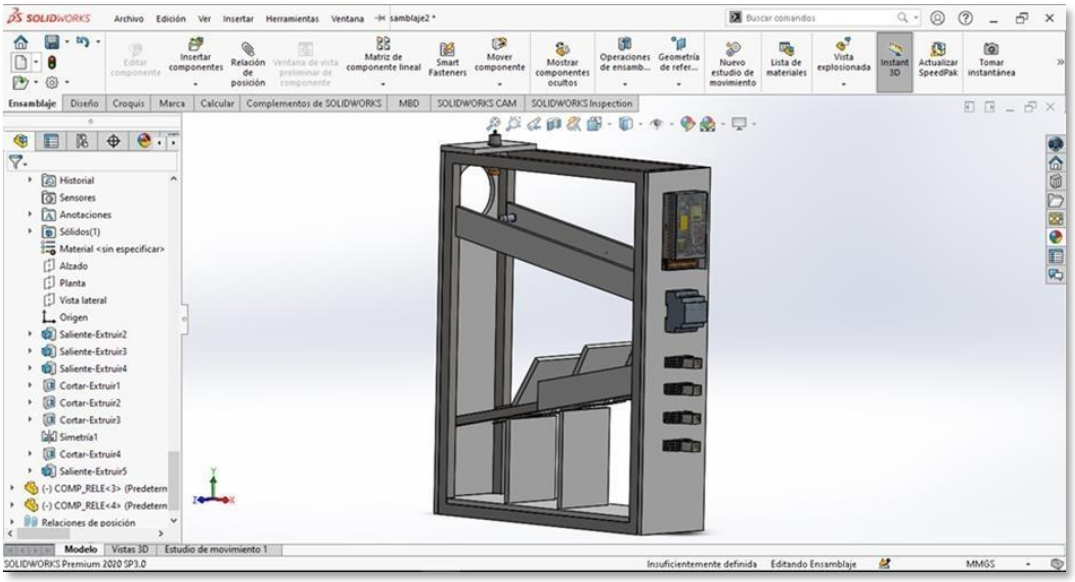

Figure 18: Assembly project - Solidworks (View 1) Source:
Own elaboration

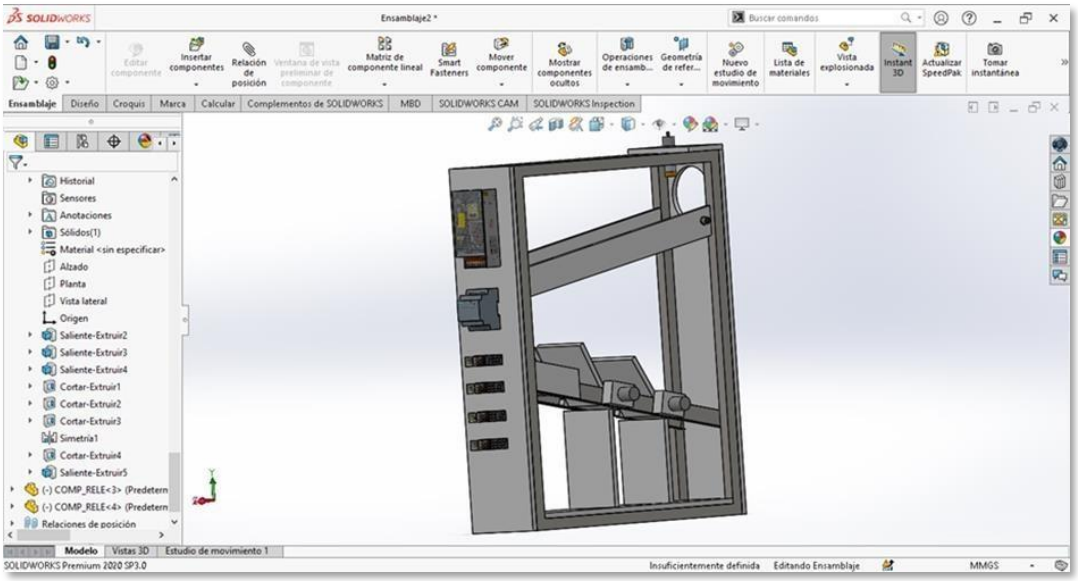

Figure 19: Assembly project - Solidworks (View 2) Source:
Own elaboration

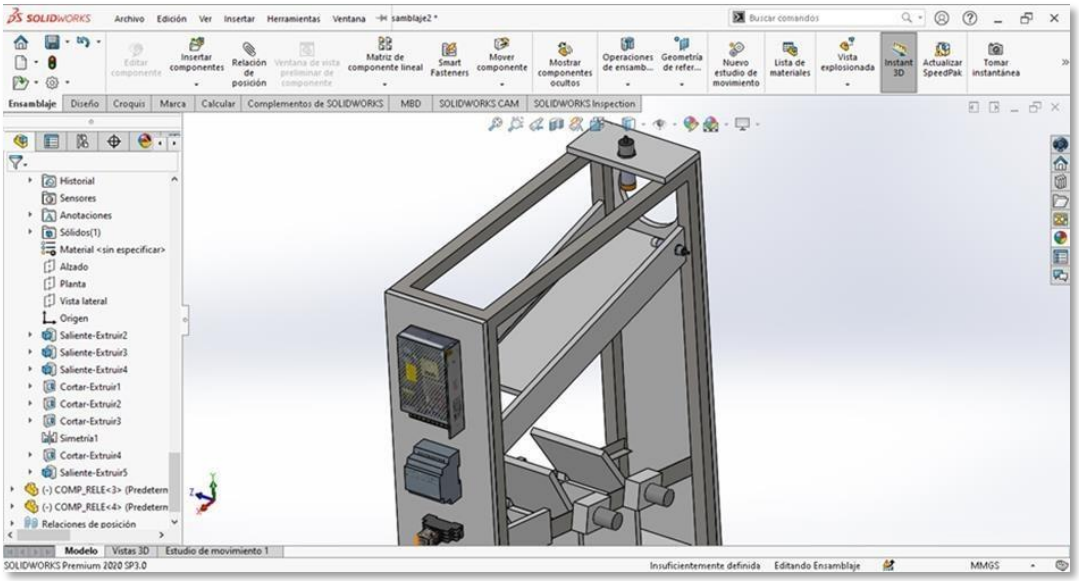

Figure 20: Assembly project - Solidworks (View 3) Source:
Own elaboration

4. DESIGN OF THE PROPOSAL TO AUTOMATE THE PROJECT

4.1. Detailed description of the proposed process

The first scope of the implemented solid waste sorting machine comprises three sections to differentiate materials such as metal, plastic and paper. The developed prototype has a PLC, which has the function of executing the previously designed programming. One of the elements that were used a lot in the project are the sensors.

The way of detecting the materials that enter the machine is as follows; the capacitive sensor captures the plastics and in addition to this characteristic, it also considers the mass, size and path, also for the project we required inductive sensors that detect the presence of ferrous materials.

In the creation of this project also played an important role the motors able to ensure the continuous operation of the devices connected directly or indirectly to the system, finally the stepper motors that convert digital pulses or electrical pulses into a mechanical cycle.

The image below shows the prototype of the project.

Figure 21: Project structure Source:
Own elaboration

The prototype was designed with the objective of ensuring that the sensors in question perform their function in an optimal manner.

4.2. Flow diagrams

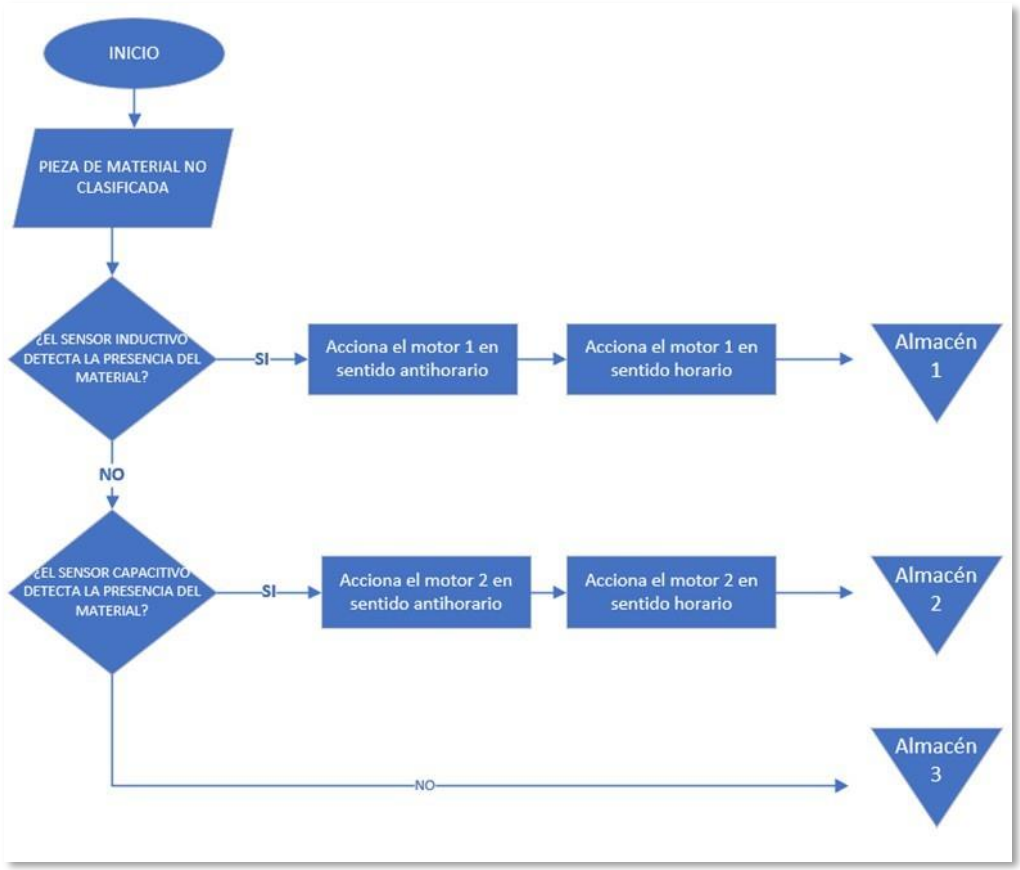

Figure 22: Process flow diagram Source: Own elaboration

4.3. Process analysis diagram

Descripción	Cantidad	Distancia (cm)	Tiempo (s)	Símbolo	Observaciones
ingreso de desecho no clasificado	1		2		Se ingresaran latas de formas cilindricas
Sensor envía pulso de reconocieminto de material en 5	1		5		Tocar la lapta con el sensor
Transporte de lata por rampa reconocedora	1		3		
Transporte de lata por rampa de selección	1		4		
Elebación de compuerta	1		5		La compuerta se abrirá mientras la lata va cayendo
Caida de objeto por compuerta de clasificación de material	1		1		Después de la caida la puerta se cerrará
Revisar que es el compartimiento correcto	1		5		
Alamacenar botellas	1		0		Revisaremos el tipo de amterial
TOTAL	8	0	25		

Figure 23: Process WTP Source: Own elaboration

4.4. Programming

To achieve the correct operation of the project, a PLC was needed with its respective inputs and outputs, which were programmed using the LOGO Soft Comfort V8.3 program.

The first step is to select "Contact diagram (KOP)" to make our electrical schematic. Then we select in the "Instructions" section the constant "Normally open contact" which will be the input I1 for the inductive sensor. Then we connect two timers which are "Edge-triggered sweep relay" (t001 and t002) which will be connected to the outputs Q2 and Q1 respectively which give the counterclockwise and clockwise direction to the motors with a pulse duration of 1 second and the second relay with a pause of 4 seconds.

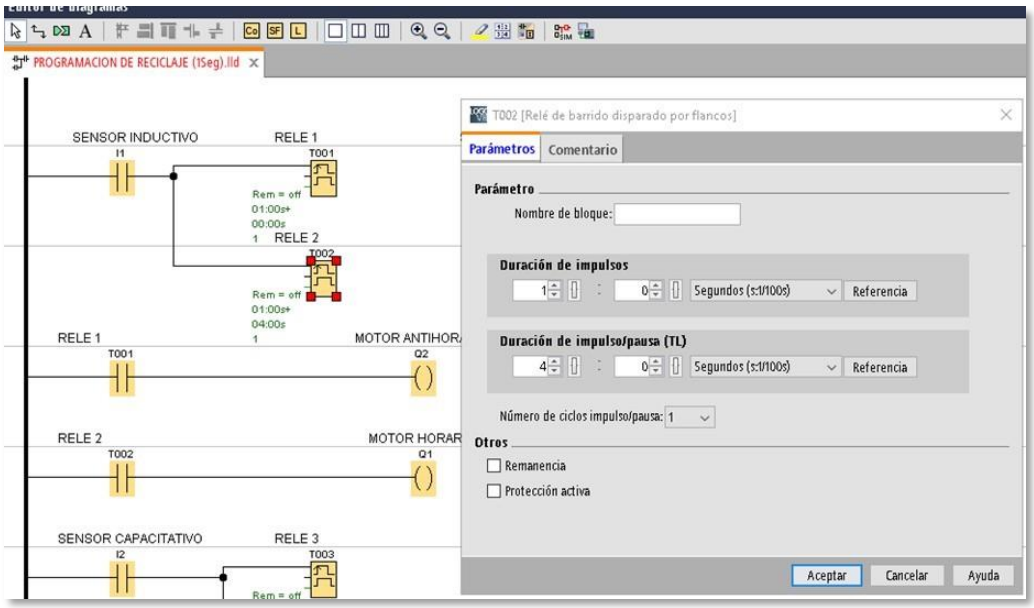

Figure 24: Capture of time scheduling in the LOGO program Source: Own elaboration

The same procedure is repeated for the capacitive sensor, which is located at input I2 and with outputs Q3 and Q4 in the PLC. It is important to take into account in which ports the components are connected to specify these inputs and outputs in the PLC.

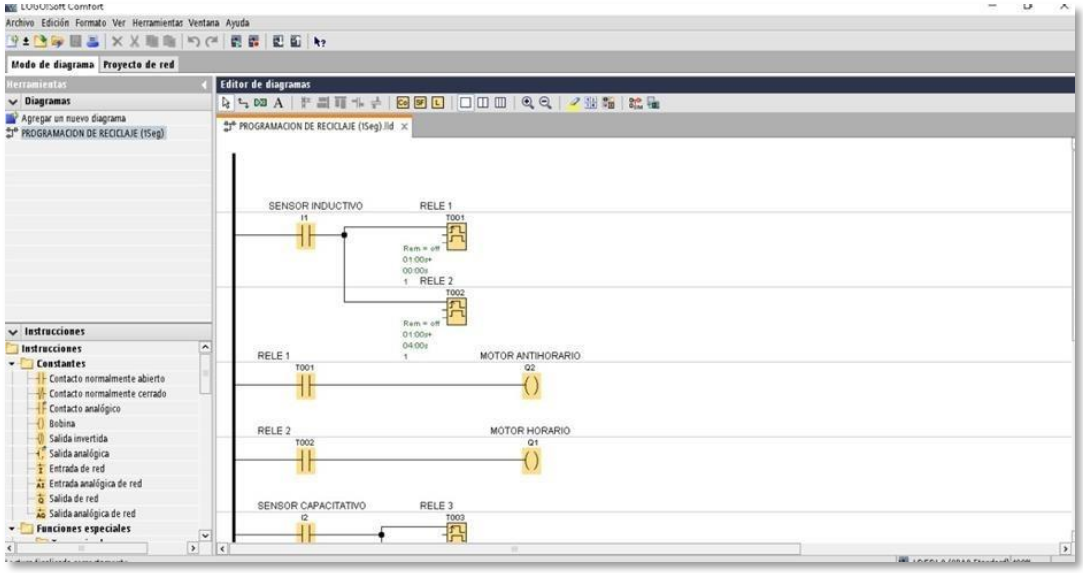

Figure 25: Capture of the PLC programming in the LOGO program (Part 1)
Source: Own elaboration

We proceed to simulate in the same program to verify its correct operation, for which only the "Simulation" option is selected and the inputs I1 and I2 are turned on, verifying that the energy flow characteristic of red color reaches the outputs Q1, Q2, Q3 and Q4 giving us to understand that the program gives a correct operation.

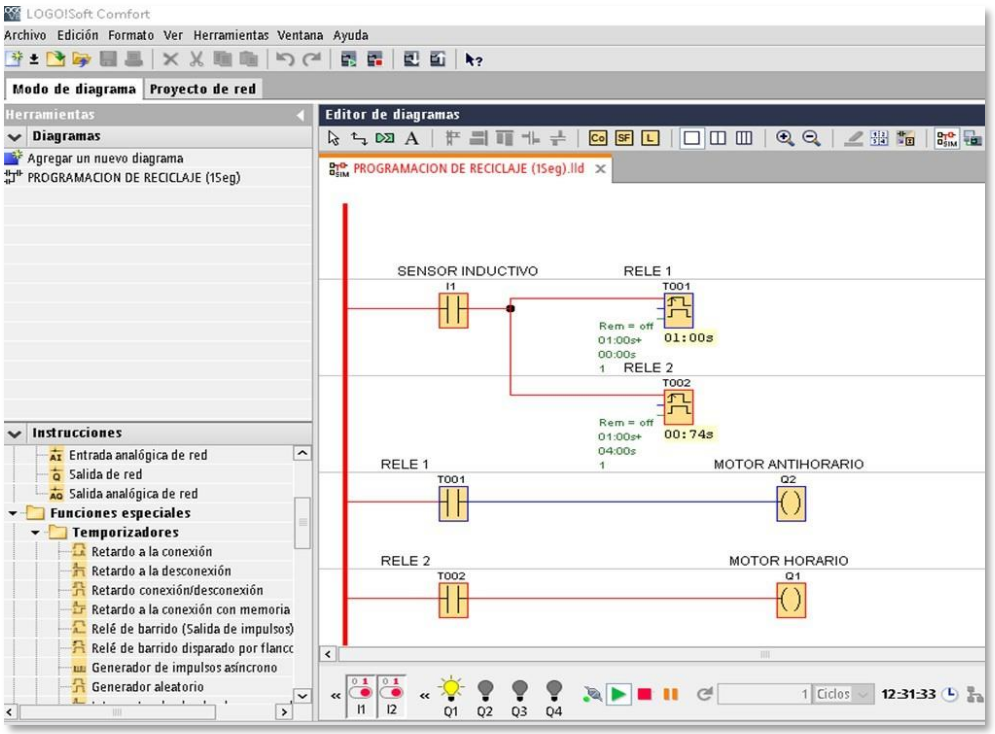

Figure 26: Capture of the PLC programming in the LOGO program (Part 2)
Source: Own elaboration

Once the schematic is correctly functional, we proceed to transfer the program to the PLC, for which we go to the section "Tools -> Transfer - Transfer - PLC".

> PC->LOGO!". It is updated to detect our PLC which was given a local IP automatically by the laptop that was programmed. Select our PLC and hit "Test". Once linked, it will start transferring the programming to the PLC and send a message that the transfer was successful.

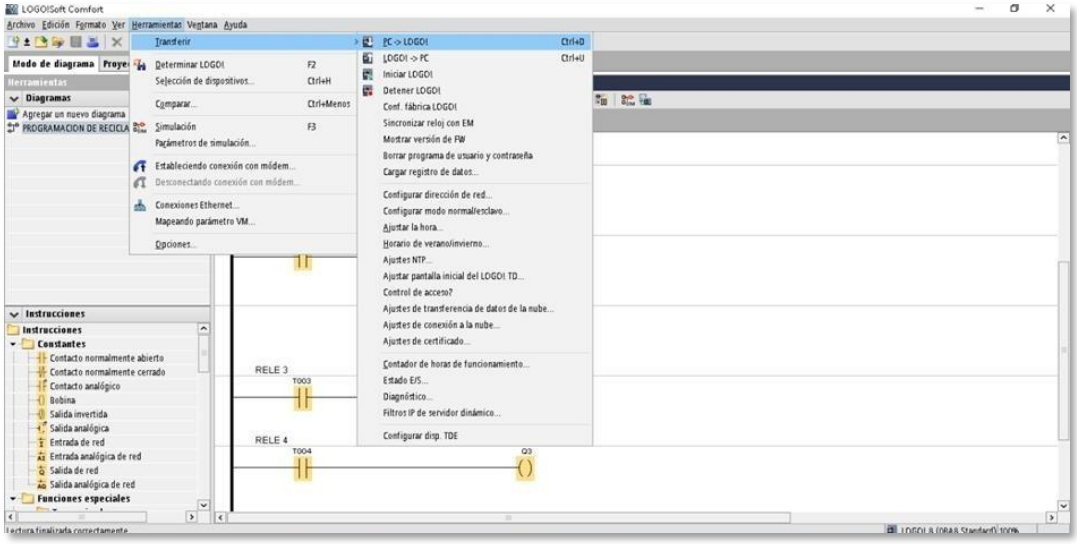

Figure 27: Capture of the moment when the programming is sent to the PLC LOGO (Part 1)
Source: Own elaboration

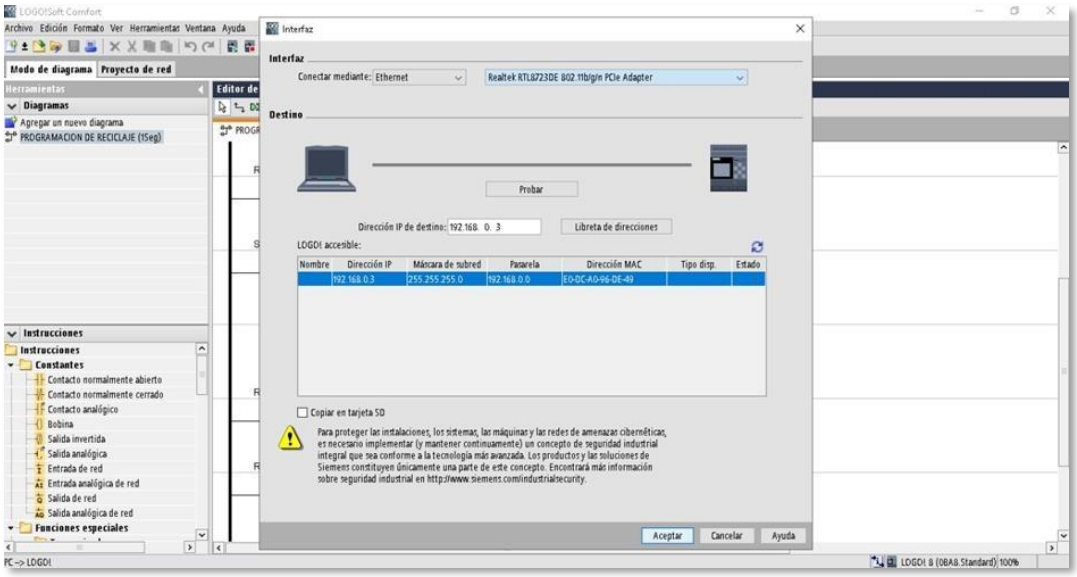

Figure 28: Capture of the moment when the programming is sent to the PLC LOGO (Part 2)
Source: Own elaboration

5. INVESTMENT AND OPERATING COSTS

5.1. Component purchase costs and budget

The total cost of the entire project was S/1128.00 soles, which is an adequate and low amount for all the benefits that will be obtained by implementing our waste sorting machine, which are mentioned in the following chapter.

Table 01. Production costs of the waste sorting machine

MAQUINA CLASIFICADORA				
Componente	**Caracteristicas**	**Cantidad**	**P.U.**	**Importe total**
Réle	Dispositivo electromagnético que funciona como interruptor en circuitos eléctricos independientes.	4	15	S/60
Motor 24 voltios	Es un motor eléctrico de corriente continua, en el cual su funcionamiento es a 24 voltios.	2	24	S/48
Fuente 220 voltios a 24 voltios	Fuente de voltaje, posee dos terminales encargados de generar el voltaje de salida independientemente de las cargas que pueda recibir proporcionando asi energia.	1	40	S/40
Sensor inductivo	Sensor eléctrico encargado de determinar elementos ferrosos a una determinada distancia.	1	55	S/55
Sensor capacitivo	sensor eléctrico encargado de determinar cualquier tipo de material ya sea ferroso o no ferroso a una determinada distancia.	1	50	S/50
PLC Logo	controladores lógicos programables, mediante un programa estos son programados y configurados de acuerdo a los requerimientos necesarios.	1	430	S/430
Cable ethernet	Cable de red para conectar a un rout	1	10	S/10
Estructura	Estructura metalica.	1	300	S/300
Adicionales	Cables, herramientas y seguros de plasticos.	1	100	S/100
TOTAL				**S/1,093**

Source: Own elaboration

6. BENEFITS

The benefits of implementing a sorting machine for metal, plastic and paper waste would generate a recycling culture in the next generations, thus creating a sustainable and eco-friendly future.

The advantages of the project would be the following:

- Interactive recycling alternative, as it is a simple automated process that would be attractive to children.
- Raise people's awareness to learn to recycle on an ongoing basis.
- Fundamental support in preserving the environment.
- Generate savings at different points, since machines that require large amounts of electricity are used for the production of plastics, thus saving water and being profitable in the long term.
- Minimize the raw material costs that produced the product that is now being discarded.

6.1. Benefits for the industry

- Lower production costs.
- Minimizes environmental pollution.
- Carbon dioxide emissions would be considerably reduced.
- As for plastic waste, it is processed by a machine to obtain derivatives such as plastic oil and diesel by crude oil distillation units.
- Scrap metal can avoid the use of new raw materials and energy, since according to data from the European Metal Packaging (EMPAC), steel made 100% from scrap requires 75% less energy than steel made from virgin raw materials.

6.2. Benefits for humanity

- Avoid reducing waste that pollutes the environment.
- Avoids the massive exploitation of environmental resources by reusing products already processed and discarded after use.
- Minimize production costs when obtained from recycling.
- The opportunity to enjoy a sustainable and less polluting economy. Raw material in the recycling of discarded products.

7. ENVIRONMENTAL IMPACT

According to the Ministry of the Environment (Minam), in 2018, it seeks to make everyone aware of the importance of treating waste properly, minimizing waste generation, reusing and taking advantage of those that have commercial value and can be converted into new products. In Peru there are enormous opportunities to increase recycling, since only 1.9% of the total reusable solid waste generated is recycled.

Seeing the statistics and information obtained from the studies conducted by Minan, this project is designed to be an idea to be implemented in schools, colleges and universities in order to instill the importance and the great benefits that this recycling system can bring with this solid waste material selector.

This process in which waste materials are collected and transformed into new materials that can be used or sold as new products or raw materials.

Industrial recycling can be done through elements such as bottles, cans, paper or metals. For this, some industries carry out certain processes that allow them to obtain totally clean and new products, which are returned to the market.

The purpose of recycling through our solid waste material selector is to find a solution to the problem of waste accumulation and to increase the percentage of utilization of waste that is low and can be better, whether it is recovered directly or indirectly.

The importance of recycling extends not only to the preservation of raw materials, but also to the reduction of the energy required to manufacture various products.

Due to the current problem of improper handling of solid waste, we sought a way to achieve optimization by implementing automation to the current recycling process, where through our sorting machine we seek to give a second chance to bottles, cans, paper, either as raw materials or as renewable products. Let's remember that the use of recycled products reduces energy consumption, thus reducing CO2 emissions, minimizing the levels of greenhouse effect and acid rain caused by this gas.

Figure 29: Team Photo - (From left to right): Franco Moreno, Miguel Taipe, Jesus Arango, Lorena Vela, Leonel Guerrero, Carlos Languasco, Gerardo Ríos, Luigui Gonzaga and José Loza Source: Own elaboration

Figure 30: Waste sorting machine Source: Own elaboration

CONCLUSIONS

1. Through this project we were able to design, build and automate a waste sorting machine, thus facilitating the recycling process, optimizing and supporting the correct management of waste.
2. A prototype of the structure of the waste sorting machine was implemented, since at the moment it only sorts small materials (the size of a hand).
3. Using the LOGO! program, the project was successfully programmed to fulfill its function of waste classification. It could be said that the programming was simple and basic components were used.
4. It was possible to increase the volumes of recycled materials with the small-scale automated prototype, suggesting that the sorting machine is functional and that a larger-scale design could be made to support larger weights and sizes.

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