Chapter 3 Value chain design to open a recycling plant in the municipalities of Huauchinango-Xicotepec, Puebla

Capítulo 3 Diseño de la cadena de valor para abrir una planta de reciclaje en los municipios de Huauchinango-Xicotepec, Puebla

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Abstract

At present, the integral conservation of the environment represents one of the concerns with the greatest impact in the social sphere because the preservation and management of the environment are directly interrelated with the different productive activities that contribute to the economic and family well-being of the individuals.With population growth, the generation of urban solid waste (RSU) has increased, causing various problems that affect health, pollution and image aspects of urban sites, for this reason, it seeks to put into practice viable alternatives that lead to designing efficient recycling processes for the transformation of solid waste and the protection of natural resources located in the region and the area of influence. The exposed research develops a value chain prototype for the opening of a recycling plant making use of the Lean Manufacturing technique called VSM proposed for two production lines of MSW obtained from a recycling system of PET, cardboard and paper implementing a work methodology developed from this improvement,later a design of the physical elements (machinery) was elaborated using SolidWorks technological software; Thus, it is also concisely shown the benefits that it will bring to sustainable development and the contribution to ODS 12 through community intervention and the generation of employment sources with the creation of the recycling plant in the proposed municipality.

VSM, Recycling Plant, Prototype, Value Chain

Resumen

En la actualidad, la conservación integral del medio ambiente representa una de las preocupaciones de mayor impacto en el ámbito social debido a que la preservación y el manejo del medio ambiente se interrelacionan directamente con las diferentes actividades productivas que contribuyen al bienestar económico y familiar de los individuos. Con el crecimiento poblacional, la generación de residuos sólidos urbanos (RSU) se ha incrementado, provocando diversos problemas que afectan la salud, la contaminación y los aspectos de imagen de los sitios urbanos, por esta razón, se busca poner en práctica alternativas viables que lleven a diseñar procesos de reciclaje eficientes para la transformación de los residuos sólidos y la protección de los recursos naturales ubicados en la región y el área de influencia. La investigación expuesta desarrolla un prototipo de cadena de valor para la apertura de una planta de reciclaje haciendo uso de la técnica de Lean Manufacturing denominada VSM propuesta para dos líneas de producción de RSU obtenidas de un sistema de reciclaje de PET, cartón y papel implementando una metodología de trabajo desarrollada a partir de esta mejora, posteriormente se elaboró un diseño de los elementos físicos (maquinaria) utilizando el software tecnológico SolidWorks; así mismo se muestra de manera concisa los beneficios que traerá al desarrollo sostenible y la contribución al ODS 12 a través de la intervención comunitaria y la generación de fuentes de empleo con la creación de la planta de reciclaje en el municipio propuesto.

VSM, Planta de reciclaje, Prototipo, Cadena de valor

3.1 Introduction

The indices of impact on the environment in Mexico grow exponentially to alarming levels, in recent years various problems have contributed to the generation of the aforementioned problem one of the factors with the greatest presence focuses on the availability and accumulation of various domestic solid waste in countries in develop which do not have physical infrastructures assigned as warehouses or processing units to promote the improvement of recycling systems,due to the lack of a feasibility analysis that supports a proposal for the construction of validated recycling plants through the application of quantitative and qualitative tools. In response to the above, a correlational study is presented through the analysis of the "VSM" value chain for the opening of a recycling plant in 2 municipalities located in the Sierra Norte of the State of Puebla. In the first instance, a feasibility study was applied analyzing the habits and opinions of the inhabitants of the aforementioned area, then the value chain was created by identifying the main products to be manufactured, the potential suppliers and the target market. In this way, the cost margins are also calculated in comparison with the already established values of similar products. In order to optimize the production process, a mapping of the value stream is designed, determining the optimal operations involved in the processing of the selected waste. Subsequently, a prototype of a potentially recyclable VSM processing line is designed, in the SolidWorks technological software it shows the necessary machinery for each operating station.

Applied research will enrich the sustainable development of the region by directly contributing to Sustainable Development Goal number 12 of the 2030 Agenda (ODS 12), efficiently managing a work system for the elimination of solid waste from the inhabitants, managing efficiently the availability of material resources of the municipalities.

3.2 Problem Statement

The municipality of Huauchinango belonging to the Sierra Norte de Puebla does not have an official sanitary landfill for the treatment of solid waste, causing serious environmental problems for society that are reflected in: a negative urban image, pollution of streets and rivers that causes outbreaks infection, improper incineration practices that release toxic gases into the atmosphere and the environment in which they are located; This growing problem stems from the exponential growth of the population.

According to the percentage of birth (1.70%) and mortality and (1.55%) extracted from INEGI, it was diagnosed that by the year 2022 the municipality of Huauchinango will have approximately 110,022 inhabitants, of which each inhabitant discar an average of 750 grams of RSU daily, generating a total of 82,516.5 kilograms per day. These wastes end their service period in dumps or landfills; Most of the time these materials are recoverable and are suitable to be subjected to recycling processes, in the aforementioned municipalities 9.24% of the total garbage corresponds to the classification of PET and its derivatives, while paper and cardboard make up the 20.64%.

Recycling processes allow the use of the various resources manufactured in sub-processes, positively lengthening the use of the life cycle in subsequent activities to make discarded; The sale of products that result from the combination of elements extracted from recycling with various raw materials generates a source of income for the social sector, thus also ensuring the consumption of goods and resources that will progressively reduce the current ecological footprint. The construction of industries, businesses that are dedicated to recycling contribute directly to ODS 12; With the opening of the recycling plant, a viable solution is evidenced to turn the problem of excess waste into an opportunity for sustainable growth for the municipality.

3.3 Justification

Currently, the amount of MSW (Urban Solid Waste) produced is increasing due to the fact that the population growth rate has constantly increased and there is no methodology in the garbage classification and recycling processes. According to the National Institute of Geography and Statistics (INEGI), more than 2,116 tons of plastic waste are generated annually, and it is essential to create organizations that contemplate the recovery of different components by applying manufacturing methodologies corresponding to recycling.

The State of Puebla is considered one of the states with a reduced culture with respect to implementing recycling systems, on average it reuses only 30% of the total MSW (INECC-SEMARNAT, 2016), a situation that is reflected locally in minimum levels of recycling. The described proposal focuses on two of the main municipalities of the Sierra Norte de Puebla: Huauchinango and Xicotepec, which together have a population of approximately 197,782 in these regions, minor efforts have been concentrated to introduce methods that redirect the correct management of MSW. At the beginning of 2010, seeking to introduce a differentiation collection method, the program known as "My Clean Huauchi" was opened, reaching a reduction rate of 30% of the waste generated being sent to the sanitary landfill that was in use until that date, The planning did not reach the proposed goals and the mixed collection methodology was reintegrated, which is made up of citizen participation and direct delivery to the collection transport units; In subsequent periods, a lack of control was noticed in the final placement of the RSU, depositing them in unauthorized places, significantly reducing the environmental quality indicator in various areas and area of influence, affecting the urban image and the naming of the municipality as a magical town (Ministry of Tourism, 2017).

Considering that in the two aforementioned municipalities considerable amounts of potentially recyclable garbage are discarded daily, of which 9.24% is PET and 20.64% is paper-cardboard and taking into account the economic benefit that will result from the sale of these wastes to superior processing plants, a value chain prototype is proposed for the opening of a dual recycling plant for paper-cardboard and PET

3.4 Objectives

3.4.1 General objective

To develop a value chain prototype for the opening of a recycling plant in the Municipality of Huauchinango providing a positive benefit to the sustainable development of the region, through the application of the VSM analysis tool, the use of software, technological and the evaluation of variables involved in the recycling process.

3.4.2 Specific objectives

- Application of a data collection instrument to know, identify and determine the degree of acceptance and opportunity to open the recycling plant in the Municipality of Huauchinango.

- Diagnose the optimal and sustainable cardboard, paper and PET transformation processes of a recycling plant through a value mapping (VSM) to detect the activities that do not add value to the final product.

- Develop a prototype of a PET and cardboard recycling line through SolidWorks technological design software.

3.5 Scope of the investigation

- The documentary research focuses on the Huauchinango and Xicotepec regions, the data presented correspond to these two areas.

- The VSM model includes two production lines (line A = PET, line B = Paper and Cardboard) according to the amounts of waste produced in the two regions.

- A model of a recycling plant is shown; designed in SolidWorks describing the characteristics of the machinery and optimal working conditions.

3.6 Theoretical Framework

In the first instance, mention will be made of the term environment due to the importance it represents in the development of this application. The environment is defined as a set of physical and biological characteristics that interact between the different components that make up a habitat or ecosystem (Gabriel Quadri, 2006). Next, concepts related to the subject of study are presented.

3.6.1 Recycling

Chang Marcos Alegre, (2005) indicates: "Recycling is the result of a series of activities, through which materials that would become waste are diverted, and separated, collected and processed to make used as raw materials in the manufacture of articles that previously they were made only with virgin raw material. Recycling is to carry out a practical and concise method that originates from one thing to another, it is done in a previous way that is used for its progression, it is an ecological measure to promote reuse that carries with it the reduction of waste and the reduction of the consumption of natural resources (Torres Guarniz, 2016).

3.6.2 Types of recycling

*Selective Collection***:** It is the separation of the components of the garbage, for their direct recovery. For the success of this system, citizen participation is needed, on the one hand, by having to select at source (homes) and deposit the waste to be recovered in separate containers, the selective collection of solid waste implies that the fractions are separated at the source and later collected also separately; This separation greatly reduces the mixing and contamination of materials, which consequently increases their quality (Torres Guarniz, 2016).

Selection Global: It is a not recommended system for our reality, since it is more expensive and complicated. It is a technique based on gross or global waste, used in the mining and metallurgical industry, such as pneumatic crushing, screening and classification, wet, electromagnetic, electrostatic, optical and flotation separations by foams for obtaining and purifying metals and glasses. It is a process that is not recommended because it is expensive and presents great difficulty. It is a process through the garbage discarded in the industry, and they need to be classified to obtain matter such as glass and minerals. (Reyes Curcio, Pellegrini Blanco & Reyes Gil, 2015).

Therefore, it is advisable to carry out selective collection because it not only encourages the recycling and the valuation of municipal solid waste, but also serves to separate hazardous waste thereof.

Recycling of paper

It consists of making paper, using as raw material used or not used papers, such as: paper scraps, cardboard and cardboard, generated during the manufacturing processes of these materials or their transformation into other articles, or also generated in printING. Recycled paper contains secondary fibers that is they have already passed through a paper machine at least once with substances that are impervious to moisture, contaminated with chemicals harmful to health such as: toilet paper, paper towels, napkins and tissues. (Escobar, Quintero and Serradas, 2006)

*The recycling of plastics***:**

It can be classified according to four types of technologies: primary, secondary, tertiary and quaternary.

Primary or pre-consumer recycling: It is the recovery of these wastes carried out in the generating industry itself or by other processing companies. It consists of the transformation of plastic waste through conventional processing technologies, into products with characteristics equivalent to those of products made from virgin resins. These wastes are made up of defective artifacts, discards from molds or from cutting and processing sectors. (Escobar, Quintero, Serradas, 2006).

Secondary or post-consumer recycling**:** It is the transformation of plastic waste from products thrown away. The materials that enter this group come from garbage dumps, composting plants, selective collection systems, scrap metal, goats. They are made up of the most different types of material and resins, which requires a good separation, so that they can be reused (Escobar, Quintero, Serradas, 2006).

Tertiary recycling**:** It is the transformation of plastic waste into chemical products and fuels, through thermochemical processes (pyrolysis, catalytic conversion). Through these processes, plastic materials are transformed into raw materials, which can again originate virgin resins or other substances of interest to the industry, such as gases and oils (Escobar, Quintero, & Serradas, 2006).

3.6.3 Value chain

The value chain of an organization includes the main activities that create value for customers and support activities. The chain also makes it possible to identify the different costs incurred by an organization through the different activities that make up its production process, which is why it is an essential element in determining the cost structure of a company. Each activity in the value chain incurs costs and limits assets, in order to achieve their due analysis and consideration, they allow to improve the techno-economic efficiency of a company, a group of companies or a certain industrial sector. From a strategic point of view, the value chain of a company and the way in which it carries out each activity reflects the evolution of its own business and its internal operations; the strategy, the approaches used in its execution and the fundamental economics of the activities themselves. Consequently, it is normal for the heat chains of rival companies to differ, a condition that complicates the task of evaluating the relative cost positions of rivals. (Quintero & Sánchez, 2006)

3.6.4 Value Stream Mapping (VSM)

The mapping of the value stream or VSM (Value Stream Mapping), is a very important Lean tool, it contains all the actions, both those that add and do not add value within the manufacture of a product from the raw material to the finished product in customer's hands. The VSM focuses more on the flow of processes and thus be able to identify improvent areas (Villaseñor, 2007, as cited in Masapanta, 2014).

While for Paredes Rodríguez (2017) Value Stream Mapping or value chain mapping (VSM) is a Lean Manufacturing management tool that uses symbols, metrics and arrows to show and improve the flow of inventory and information required to generate a product or service that is delivered to a consumer, seeking that he only pays for the activities that generate value to the product.

3.6.5 Prototype

According to the RAE (2020) a prototype is the original copy or first mold in which a figure or something else is manufactured. The prototype is, in a general way, a preliminary model of the product that is being designed; As such, this prototype can include the representation of the object, the demonstration of its characteristics or the simulation of the functionality of the product (Maner, 2013).

Inspirational prototypes are developed in the earliest stages of projects and with the simplest and cheapest means possible. Its objective is to explore the main aspects that define a problem or opportunity and facilitate the search for more and better solutions. (CORFO, 2016)

The purpose of evolution prototypes is to mature or improve one or more previously generated prototypes. What is sought with them is to be able to continuously learn and make failure a useful and integral aspect of the innovation process. (CORFO, 2016)

The validation prototypes (type of prototype developed in this application) are intended to validate, through a structured process, the different hypotheses on which the solution is based when it is close to its final version. (CORFO, 2016)

3.7 Methodology

3.7.1 Questions to investigate

- What is the optimal recycling procedure for paper, cardboard and PET?
- What machinery and tools make up a recycling plant?
- What value engineering tool can be useful to analyze the procedure of a recycling plant?
- What range of productive logistics problems can VSM address for the opening a recycling plant?

3.7.2 Tipe of investigation

The research carried out is exploratory-correlational. According to Hernández (2010), exploratory analysis procedures are carried out when the objective is to examine a poorly studied topic or research problem, about which there are many doubts or which has not been addressed before. That is, when the review of the literature revealed that there are only non-researched guides and ideas vaguely related to the study problem, or if we want to inquire about topics and areas from new perspectives. So far there are no studies that allow us to know the degree of acceptance and feasibility for the opening of a recycling plant in Huauchinango. While the same author establishes that correlational studies are intended to know the relationship or degree of association that exists between two or more concepts, categories or variables in a particular context. In this research, in addition to finding what is happening in the municipality, the possible causes that intervene in the problem raised will be analyzed. Therefore, by means of descriptive surveys, we will be able to determine the current situation of the municipality with respect to the treatment carried out to the garbage after its collection.

3.7.3 Research hypothesis

Hypothesis 1: The opening of a recycling plant in the municipalities of Huauchinango and Xicotepec will significantly reduce the existence of products derived from PET, cardboard and paper.

Hypothesis1, analyzes the decrease in damage caused to the environment, as a result of the consumption of products with Polyethylene Terephthalate (PET), cardboard and paper. With the recycling plant it is planned to process 29.87% of the potentially recyclable waste that includes PET, paper and cardboard.

Hypothesis 2: The study and analysis of the value chain, through the VSM, for the opening of a recycling plant will provide us with the necessary tools to build a prototype and adapt it to the proposed regions.

The VSM is an applicable technique in the process of improvement and redesign, based on 4 phases: diagnosis, planning, design, implementation of improvement processes. Through of this tool visualize and identify the problems or waste of the lines of production generating a competitive advantage for the establishment of guidelines that allow the flow of information between the members that make up the value process.

3.7.4 Variables

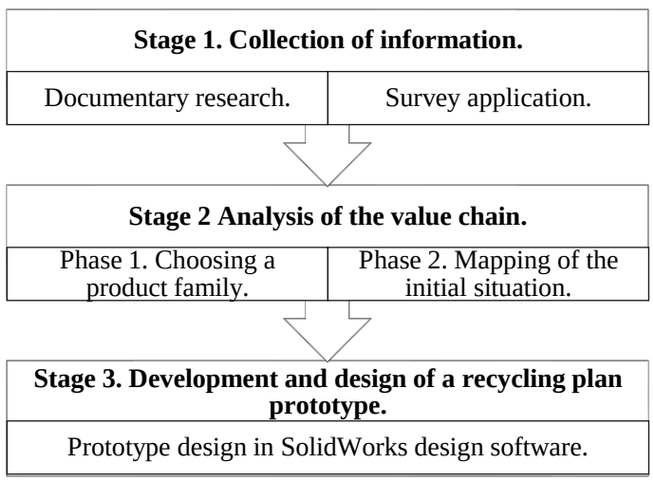
- Solid Urban Waste (MSW): They are considered organic and inorganic waste produced by a social community, they are characterized by being sub-classified into various groups; 70% of these are sent to clandestine garbage dumps or deposited in different parts of the region, affecting the urban image and the health of the members of the different communities.

- Recycling plant: Physical infrastructure that is identified as contributing to the correct transformation process of the MSW, within the processes carried out in the production lines, different materials such as PET, paper and cardboard are transformed and reused, providing them with a second use and obtaining an economic benefit from the sale of the products obtained.

3.7.5 Methodological process

Next, the methodological process applied to achieve the proposed objectives is described (Figure 3.1 Methodology used).

Figure 3.1 Methodology used



Source: Own elaboration

The different stages are described below:

3.7.6 Stage 1. Collection of information to determine degree of need and acceptance of the opening of a recycling plant

Stage 1 was carried out by conducting a documentary analysis supported by the application of techniques corresponding to field research; Through the documentary, information related to existing cases of recycling plants in the state, as well as the country, was collected. The current advantages of opening a recycling plant were also studied.

In the field research, a survey was designed and implemented as an instrument for collecting information; The survey was structured through 10 multiple-response questions related to: the number of people living in your home, the approximate amount of waste it generates, the knowledge you have about waste treatment as well as the advantages proposed by the waste separation, finally the degree of acceptance of the opening of a recycling plant in the region (Table 3.1 Methodology used**.**).

Table 3.1 Survey questions

N	Question
1	¿How many inhabitants are part of your household?
2	¿How do you rate the garbage problema in your locality, neighborhood, or municipality?
3	How much waste do you normally accumulate per day?
4	¿In your home do you have the habit of separating recycable garbage (PET, paper and cardboard) and classify?
5	¿If you separate and classify PET, cardboard and paper in your home what do you do with them?
6	¿Do you know of any program, campaigns or movements on the classification of reciclable waste?
7	¿Would it be integrated into programs for the separation and and classification of reciclables?
8	¿If you had the opportunity to generate income with your recyclable solid waste (PET, cardboard, paper) through separation and classification, would you carry out recycling processes?

Source: Own elaboration

For the application of the survey, the following data were taken into consideration. In the first instance, the size of the study population was determined. Taking into account that the municipality of Huachinango has a population of 110022 inhabitants and Xicotepec a population of 87,760, considering that 56.96% of the total community represents the population that generates the greatest amount of recyclable MSW. It is determined that the total population of both municipalities is 112,656. Once the total population has been determined, the sample size calculation is carried out (1) using the formulation of Murray and Larry (2005) for sample size with a finite population and, taking into account the statistical values that are obtained. Indicate (Table 3.2 Statiscal values for the calculation of the study sample), a size (n) of 383 people was obtained.

$$n = \frac{\boldsymbol{N*z_a^2*p*q}}{\boldsymbol{e^2*(N-1)+z_a^2*p*q}} = \frac{(\mathbf{112656*1.96^2*.5*.5})}{((\mathbf{.05^2*112655}))+(\mathbf{1.96^2*.5*.5}))} = \mathbf{382.857} \quad (1)$$

Table 3.2 Statiscal values for the calculation of the study sample

Value corresponding to the Gauss distribution Zα= 0.05	**Z**	**1.96**
Expected prevalence of the parameter to be evaluated, in case of unknown and, considering equal probabilities to make the simple size larger.	p	0.5
1-p, 1-.5	q	0.5
Size of the population to study.	N	112,656
Mistake that is expected to be made with a good requerement of sampling.	e	.05

Source: Own elaboration

The results obtained when carrying out the survey and in conjunction with the statistical analysis, allowed to determine the habits of the members of the community with respect to the treatment. Of waste, as well as its appreciation point in relation to the opening of the recycling plant.

3.7.7 Stage 2 Analysis of the value chain

For the analysis of the value chain, a literary review was developed which allowed develop the ideal sequence to generate the value chain:

Phase 1. Selection of the family of recyclable products that are mainly produced in the Huauchinango region

The value flow system is structured based on recyclable products, which is why a quantitative analysis is carried out to establish the products that are most consumed in the region, later the technique for mapping VSM processes was selected which allowed to show the various recycling operations that constitute the manufacturing process (Rother, 1998).

The generation of RSU on average in the homes of the municipalities analyzed is established at 750 grams per inhabitant, according to the classification proposed by SEMARNAT, the percentages for each group of waste, organic, potentially recyclable and others are shown in the table (Table 3.3 Percentage of waste generated).

Table 3.3 Percentage of waste generated

Type of waste	Percentage
Organic	50%
Potenctially recyclable	30%
Others	20%
TOTAL	100%

Source: SEMARNAT

The information used to choose the family of products for the VSM study is that which corresponds to potentially recyclable waste, of which the most frequent are: PET, paper and cardboard, according to the analyzed population there is a total of 197782. Inhabitants (Huauchinango and Xicotepec), if we consider that on average they generate a total of 750 grams daily, the total RSU is 148336.5 kg, according to the classification proposed by SEMARNAT it follows that the total potentially recyclable waste is 44.501 kg, of which 9.24% is PET and 20.64% of paper and cardboard.

Phase 2. VSM (Current situation of the recycling process)

After the selection of the product family, the process began with the mapping, collecting information from similar processes that have turned out to be effective recycling plants located in other entities, for the information extraction the route of the product family was followed. Contemplating the mapping from the input stage of raw material to the output of the finished product, that is, a system called door-to-door was applied (Rother, 1998).

The analysis to carry out the mapping process originates with the knowledge and description of the optimal activities for carrying out the recycling processes for potentially recyclable Urban Solid Waste, for this the families of products were determined which by their volume and constancy were the PET, paper and cardboard, later the current state of each of the selected products was measured, in terms of its flow of quantity per unit of time, later with the adjustments and implementations of necessary lean manufacturing tools the Future measurement, in which, the flow ratio quantity per unit of product collection time should be greater, finally, a work plan is established which serves as support for the constant maintenance of the value flow of the recycling plant.

3.7.8 Description of the PET process

It is observed that the PET process contains seven operations which are described below continuation:

- **Deposit in the hopper:** The PET (bottles) is deposited in the hopper to move to the next operation.

- **De-labeling:** By means of a conveyor belt they pass to the machine so that the labels are removed from the PET bottles.

- **Grinding:** PET bottles are crushed into flakes the machine has fixed and movable blades that adjust for better performance.

- **Washing:** The flakes are washed to remove impurities and rinse the surface, it has stainless steel reaction tanks, in which the material is driven and aggressively washed. Specially designed machine impellers cause the flakes to collide with each other rather than against walls to prevent wear on the machine.

- **Spin:** It goes through a spinning process that removes the water in an economical way, preventing the temperature from lowering so that the impurities that were previously removed do not re-adhere.

- **Drying:** Consists of drying the leaflets, the greater amount of water is reused, the leaflets come out drier with the unit of the environment.

- **Packaging:** The flakes are bagged in 60 kg sacks and are stored for later commercialization.

3.7.9 Description of the paper and cardboard process

In the paper and cardboard process, it contains five operations which are described below:

- **Fill mill:** The operator is in charge of placing the paper and cardboard in the mill to that can be shredded.

- **Shredding:** An assigned operator is in charge of shredding the 100 kg of paper and cardboard, the essential thing about the shredder are its blades, This kept lubricated for smooth operation find optimal.

- **Fill press:** the paper and cardboard (already shredded) is placed in the press, inside this there is a plate that crushes it, then paper and cardboard continue to be placed until a bullet is formed and it is extracted.

- **Compact:** The operator assigned to this operation has to place the paper and cardboard and the compactor because it is made up of a metal plate that is ordered to push the raw material to an iron box and thus obtain the plates of 2x1x1.

- **Warehouse:** Bales of paper and cardboard are stored in the product warehouse finished.

Once the operational process of the recycling plant has been identified, the VSM process mapping.

3.7.10 Stage 3 Development and design of a recycling plant prototype

Considering what was obtained in the value chain mapping, in which the tools, limitations and procedures necessary for the optimal operation of a recycling plant are detailed, the design of the plant prototype will be carried out, this through the software SolidWorks design technology.

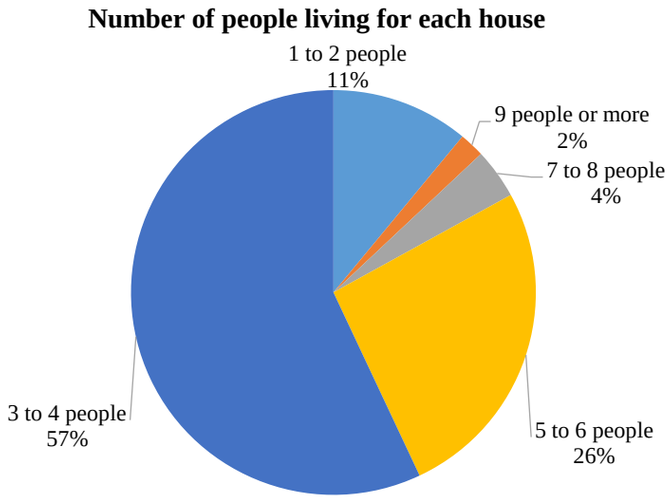
3.8 Results

3.8.1 Results of the surveys

The definition of the means for the extraction of information, as well as the collection of proposed data, and the mapping process proposed in the methodology allowed to obtain the following results for each of the stages described above (Figure 3.1 Methodology used).

The results of Stage 1 made it possible to determine the degree of need and acceptance of the opening of a recycling plant through the observation of the results obtained from the survey: As a first intervention, the number of people living in each household is analyzed (Graph 3.1 Results obtained from question 1) Therefore, we note, according to this, more than 50% of the population lives in the company of 3 to 4 people. This is reflected with the average amount of garbage that a person generates per day (1.2 Kg) representing approximately 4.8 kg of garbage, of which 30% is potentially recyclable. This question is also related to what is obtained in Graph 3.3, since it is indicated that 57% of people claim to generate between 1 and 2 kg of garbage daily.

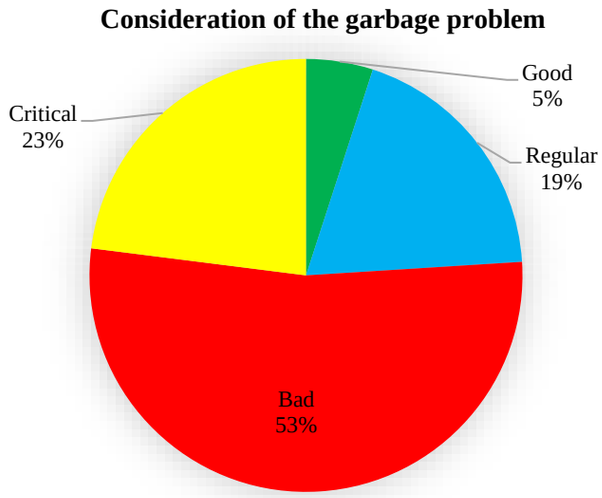
Graphic 3.1 Results obtained from question 1



Source: Own elaboration with data obtained from the survey

Subsequently, it is distinguished that 76% of the people consider the garbage problem in Huauchinango and Xicotepec at a critical and bad level (Graph 3.2 Results obtained from question 2), therefore, it is a visible problem and of relevance for their study.

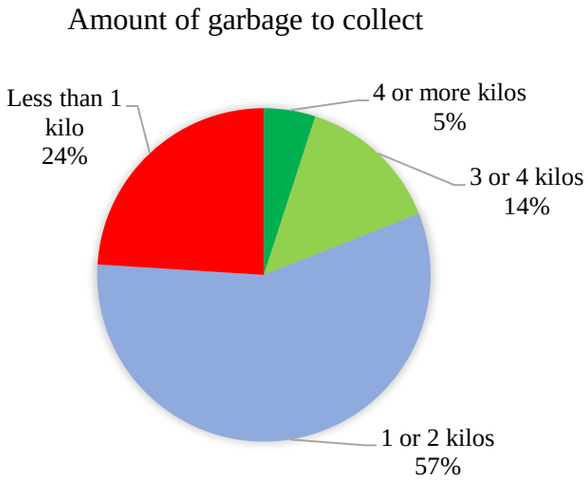
Graphic 3.2 Results obtained from question 2



Consultation Source: Own elaboration with data obtained from the survey

As mentioned above, this question is related to the number of people who live in a household, since according to this number it is the amount of garbage that is generated per dwelling unit. 57% of the people surveyed affirm that they generate between 1 and two kg daily, while 24% of them mention generating less than one kg. There are cases where the daily garbage generation is 3 to 4 kg (14% of the study population), while only 5% say they generate the amount of 4 kg or more of garbage daily. Consequently, these data are relevant, since they allow us to determine the approximate amount of garbage that can be collected for later treatment in the recycling plant (Graph 3.3 Results obtained from questions 3).

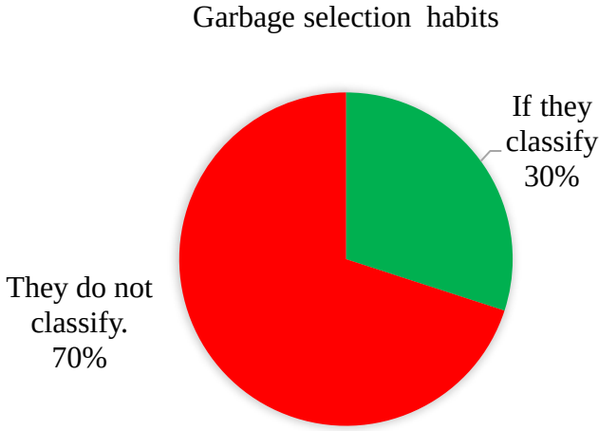
Graphic 3.3 Results obtained from questions 3



Source: Own elaboration with data obtained from the survey

Now, focusing on the habits that people have regarding waste treatment (Graph 3.4 Results obtained from questions 4), it is observed that 70% of people do not classify waste. To be discarded, a fact that is useful due to its relationship in the process of collecting waste for its subsequent treatment.

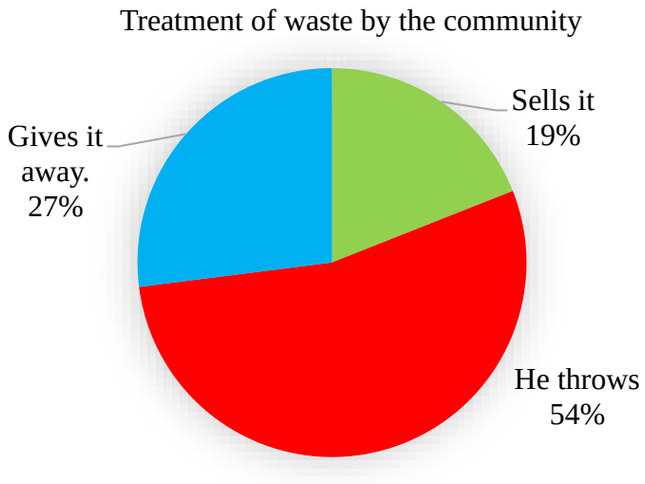
Graphic 3.4 Results obtained from questions 4



Source: Own elaboration with data obtained from the survey

Regarding the treatment of waste by the community, it is observed that 54% send it to non-established dumpsites, 19% prefer to sell it and 27% give it away to third parties people (Graph 1.5 Results obtained from questions 5).

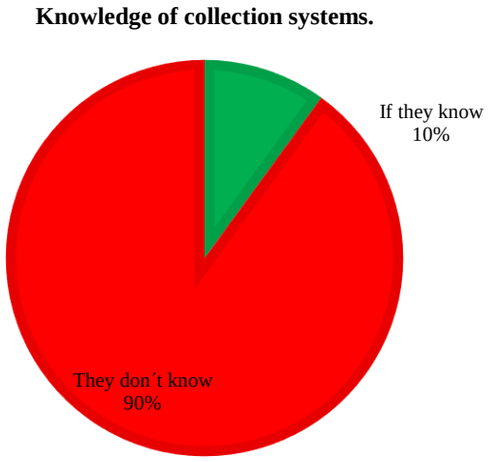
Graphic 3.5 Results obtained from questions 5



Source: Own elaboration with data obtained from the survey

In order to know the classification habits of the social environment, it was questioned about the knowledge of programs or campaigns for the separation and classification of recyclable waste, and it was found that 90% of the people are unaware of the operation of the collection systems (Graphic 3.6 Results obtained from questions 6).

Graphic 3.6 Results obtained from questions 6

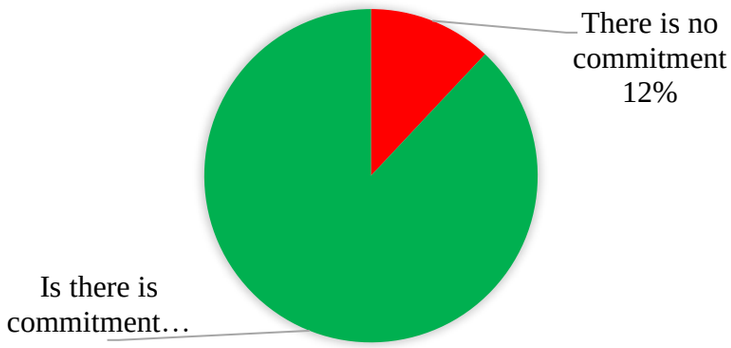


Consultation Source: Own elaboration with data obtained from the survey

The interest in knowing and taking part in recycling processes is visualized in question number 7, where 88% of the surveyed population shows a positive interest in participating in MSW separation campaigns (Graphic 3.7 Results obtained from questions 7), this being a favorable result for the promotion of recycling in the inhabitants, considering them as the main suppliers to supply the production lines of the recycling plant (Graphic 3.7 Results obtained from question 7).

Graphic 3.7 Results obtained from questions 7

Commitment to participate in collection campaigns

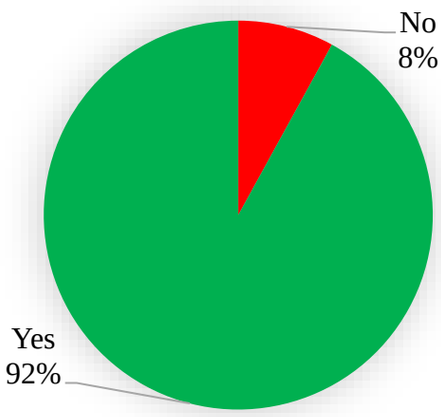


Consultation Source: Own elaboration with data obtained from the survey

Next, the perspective of the respondents was deepened, directing them towards the possibility of generating income with the sale of waste for recycling, the trend shows that 92% of them find the idea attractive (Graph 1.8 Results obtained from questions 8).

Graph 1.8 Results obtained from questions 8

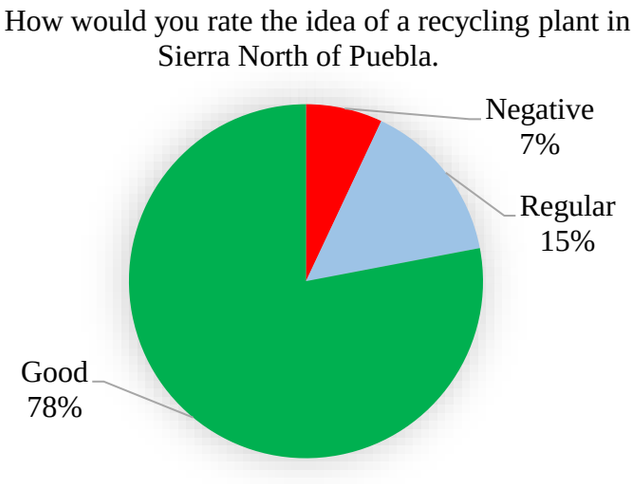
Idea of generating revenue from recycling



Consultation Source: Own elaboration with data obtained from the survey

While 78% of the population consider the opening of a recycling plant in the municipality beneficial (Graphic 3.9), indicating that it would help to reduce the environmental impact of the waste generated day by day. 15% consider the idea as regular, so it can be taken as positive for the study, and only 7% believe that the idea is bad.

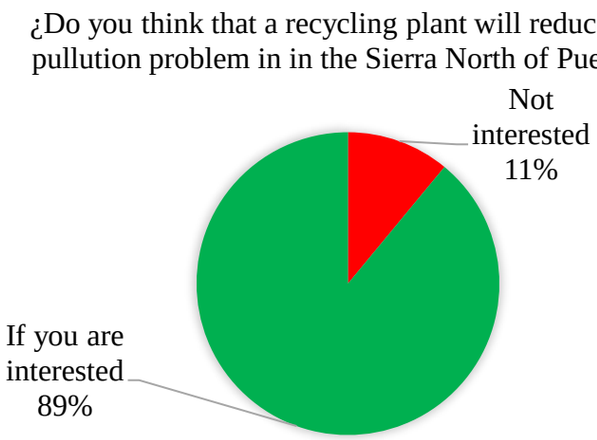
Graphic 3.9 Results obtained from questions 9



Source: Own elaboration with data obtained from the survey

To conclude the analysis of the results of the study population, it is deduced that 89% believe that the opening of a recycling plant in the Municipality would lead to a reduction in pollution in Huauchinango and Xicotepec (Graphic 3.10 Results obtained from questions 10).

Graphic 3.10 Results obtained from questions 10



Source: Own elaboration with data obtained from the survey

3.8.2 Results of the value chain analysis

Phase 1: Choice of a product family

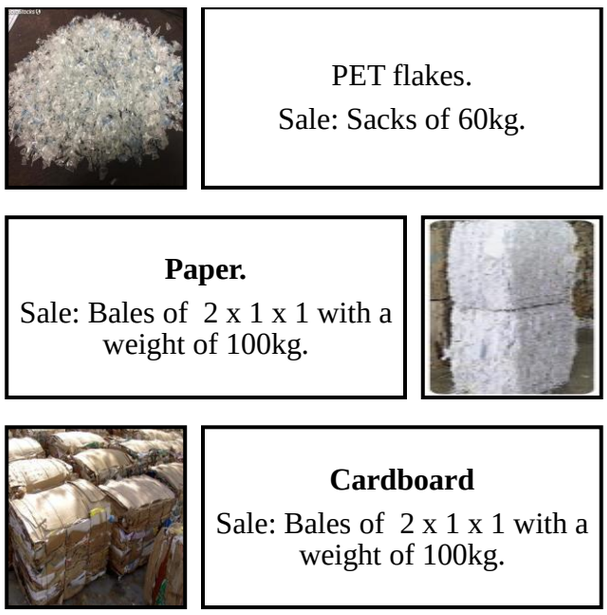
The value chain analysis process in Phase 1, conducive to the choice of the product family taking into account potentially recyclable RSU (Figure 3.2 Family of products for Value Mapping).

Figure 3.2 Family of products for Value Mapping

Source: Own elaboration

Through the choice, the final product that the company will offer is determined according to the previously selected products (Figure 3.3 Presentation of final product for sale).

Figure 3.3 Presentation of final product for sale



Source: Own elaboration

As mentioned in the methodology, in the market there are several companies and organizations dedicated to the purchase and sale of recycling, however, we undertook the task of looking for some possible clients close to our municipalities, which are dedicated to the purchase of recycled products , which is why the acceptance of the products manufactured by three main clients is proposed (RECYCLING TALISMÁN SA DE CV, COMERCIALIZADORA INDUSTRIAL MILLOP SA DE CV, RECYCLE TOGETHER) (Figure 3.4 Main customers by product sales), located in the area of influence, for the selection of the aforementioned clients, the following two variables were considered: 1) Wholesale purchasing system; the customer makes the purchase in large volumes of product. 2) logistics infrastructure (means of travel and own means of loading), considering that transportation costs are absorbed by customers, it is required that they have logistical means to transport the purchased product.

In this way, it is considered that each time the customers place the order, the recycling company, according to its planning, will execute the necessary activities with the different departments, such as raw material warehouse (collection of separated or non-separated materials), production (garbage separation area) and finishing. product warehouse (materials segmentation area), to meet the needs presented in a timely manner, as well as primary suppliers are identified considering waste collection branches for recycling in order to provide a greater economic benefit to the region (Figure 3.5 Suppliers of waste for processing in recycling plant).

Figure 3.4 Main Clients for product sales

Source: Own elaboration

Figure 3.5 Suppliers of waste for processing in recycling plant

COMERCIALIZADORA DE ACEROS ISLAS
Address: Rayón #44. Col. El Paraíso

COMPRA Y VENTA DE DESPERDICIOS INDUSTRIALES
Address: Artículo 115 Constitucional, Col. El Potro

CHATARRA
Address: Doctor Río de la Loza, Col. Santa Catarina

RECICLADORA DE MATERIALES
Address: Negrete #14 Col. Centro

BODEGA DE RECICLAJE PAPEL Y PLÁSTICO
Address: Francisco Oropeza, Col. El Ocote

RECYCLING SYSTEM
Address: Hermeregildo Galeana, Col. El Paraíso

CENTRO DE RECICLAJE LA COLMENITA
Address: El Potro

Source: Own elaboration

In the same way, the purchase and sale prices of each of these waste for treatment are established, based on what is estimated by the market value (Table 3.4 Purchase and sale price for product).

Table 3.4 Purchase and sale price for product

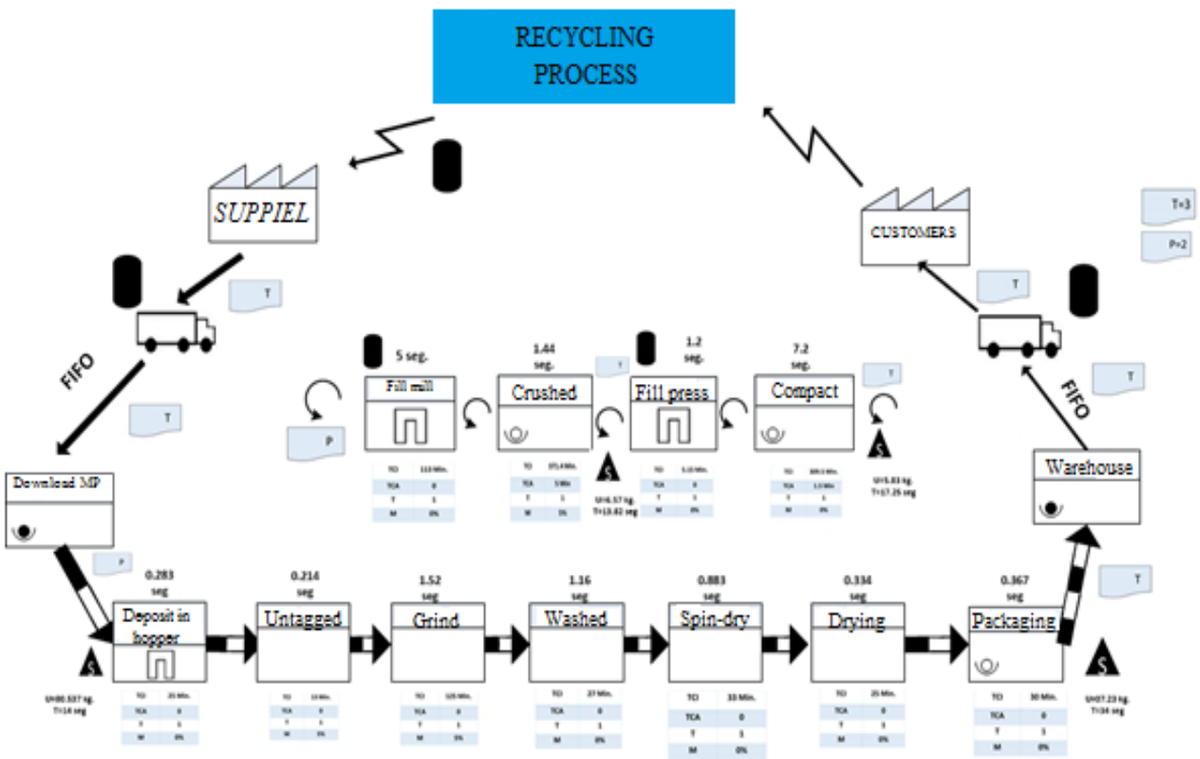
	Purchase	Sale
PET (1 kg)	$ 2.50	$ 5
Paper (1 kg)	$0.70	$ 1.50
Cardboard (1 kg)	$0.60	$ 1

Source: Own elaboration

Phase 2. Mapping the initial situation

The result obtained in phase 2 consists of the development of the current VSM, contemplating that the information flow begins when the client requests the order, established in a total of 71 sacks of flakes and 147 bales of paper and cardboard per day. Where the customer is placed at the top of the diagram and begins the flow of information from right to left, which flows to the production control department, this in turn, verifies availability of raw material and schedules the master plan of production, contemplating the requirements of PET bottles, paper and cardboard, for the elaboration of the products. For its part, the information of the material process flows from left to right, and it starts from the moment the supplier delivers the raw material. Once the above requirements had been identified, the VSM of the PET, cardboard and paper recycling process was carried out, considering the required amounts of raw material for daily processing, operating times and machinery capacities (Figure 3.6 Value mapping of the PET, paper and cardboard recycling plant, locating the bottleneck).

Figure 3.6 Value mapping of the PET, paper and cardboard recycling plant, locating the bottleneck

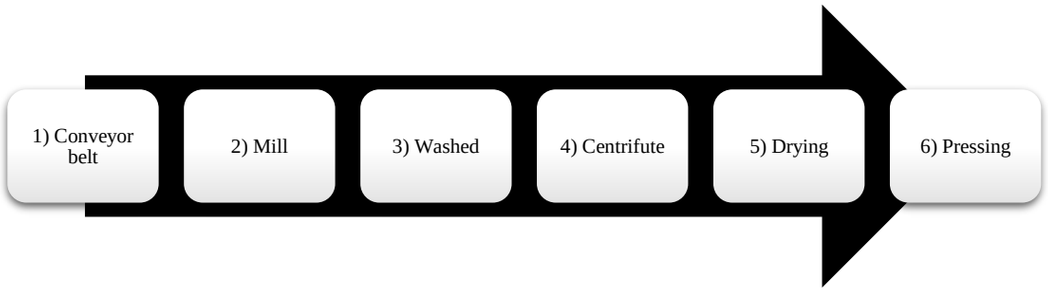


Source: Own elaboration

3.8.4 Development and design of a recycling plant prototype

The design of the recycling plant was based on the sequence of operations that constitute the production process (Figure 3.7 Operations that constitute the production process), designing through SolidWorks technological software the machinery and means of movement required for the process of transformation of PET into flakes and of the paper-cardboard in packages.

Figure 3.7 Operations that constitute the production process



Source: Own elaboration

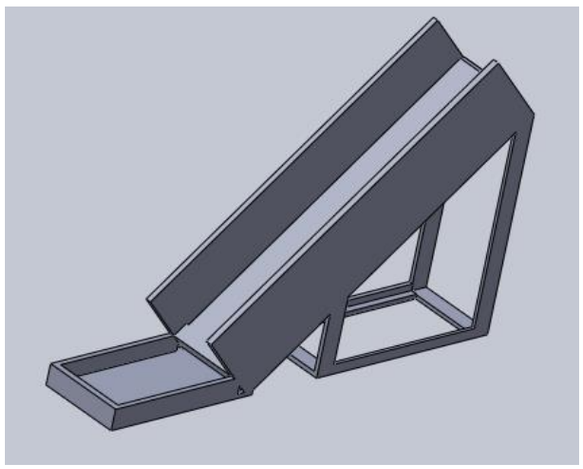
The means of movement selected and designed are chain conveyors, which due to their construction and low flexibility (Table 3.5 Conveyor Belt Characteristics) stabilize the passage of material; they are welded modular frame structures (Figure 3.8 Conveyor belt), with tall vertical sides, fully equipped with high quality bearings and gearboxes. All chain conveyors can be equipped with stepless speed control ("Modular conveyor belt from ANIS TREND d.o.o. Directindustry", 2020).

Table 3.5 Conveyor Belt Characteristics

Characteristics	
Types	Modular, spike-shaped.
Material	Metal, galvanized, elastomer.
Applications	For the paper industry, for waste treatment, for the recycling industry, for printing.
Resistence	High-strength, wear-resistant, high-strength, with anti-fatigue resistance.
Other Features	Heavy Duty, Heavy Duty, Easy Clean, Continuous, Custom, All Purpose, Chain, Sidewall, Rubber Lined
Width	Mín.: 80 cm (31,5 in)
	Máx.: 200 cm (78,7 in)
Length	Mín.: 4 m (13'01")
	Máx.: 40 m (131'02")

Source: Own elaboration with data obtained from the network

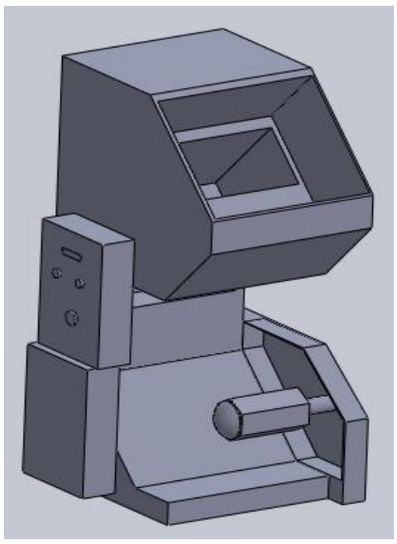
Figure 3.8 Conveyor belt



Source: Own elaboration, SolidWorks 2012

The grinding process is carried out using a grinding mill (Figure 3.9 PET mill), this consists of an inlet mouth, which allows access to the plastic pieces prepared to avoid projecting raw material to the outside, through the use of blades (Table 1.6 Features of PET Crusher Mill), the plastic pieces are cut and crushed, later they are passed to a sieve to shape the grains / flakes, to finish the finished product is sent by means of conveyor belts to the assigned warehouse.

Figure 3.9 PET mill



Source: Own elaboration, SolidWorks 2012

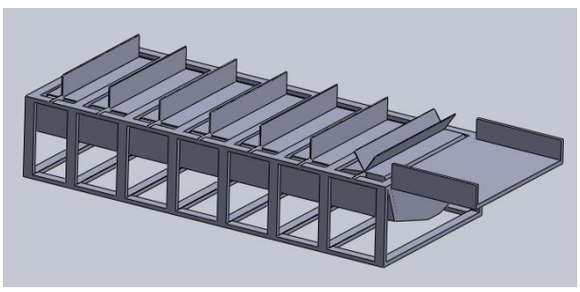
Table 3.6 Features of PET Crusher Mill

Technical characteristics	
Model	M20-Motor Eléctrico
Motor	20 HP
KW	15
V/KVA	220 V Trifásico/ 18.75 KVA
Production	Por jornada laboral
Kg/h	180-350
Blades	Varias
Type of cut	Tijera
Rotating	6
Fijas	4
Screen / Flake Size	3/4"
Blades material	Acero D2 56
Sharp frequency	Cada 8 ton
Maximum number of affiliates	45
Approximate weight	400 Kg

Source: Own elaboration with data obtained from the network

The activities that comprise the washing process are carried out in the machine called a paddle washer (Figure 3.10 Paddle Washer) which, through a complementary module (Table 1.7 Add-on module features), washes the material to remove contaminants or unwanted material spilled on the ground plastic flakes (PET, PP, PE, PS, ABS). Thus, it is also used as a means of transport between modules to move the product during the recovery cycle.

Figure 3.10 Paddle Washer



Source: Own elaboration, SolidWorks 2012

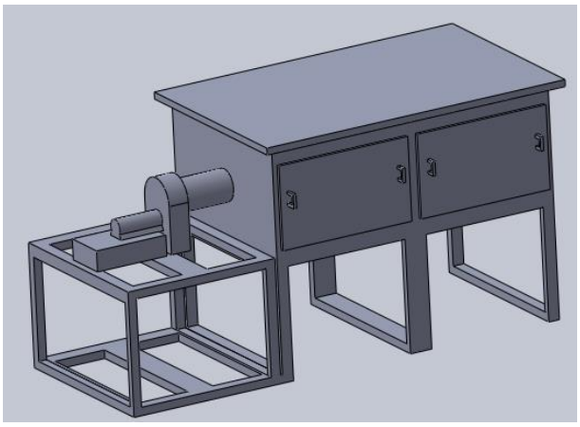
Table 3.7 Add-on module features

Characteristics	
Motor	7.5kw/11kw/22kw
Screw diameter	300mm/500mm
Speed	700-900rpm
Length	2500-3500mm

Source: Own elaboration with data obtained from the network

The operating process of centrifugation is carried out in centrifuge machines (Figure 3.11 Centrifuge), by means of these operating actions the moisture is eliminated from the flakes of plastic bottles by high-speed rotating blades. Moisture extraction is done on PP / HDPE / PET materials.

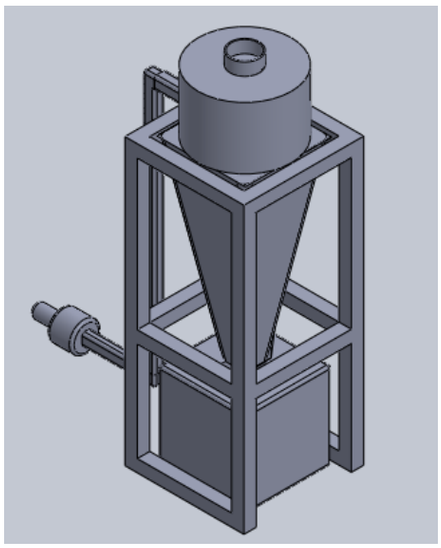
Figure 3.11 Centrifuge



Source: Own elaboration, SolidWorks 2012

The fifth stage of the recycling production process is drying, the operational actions are carried out in the dryer hopper (Figure 3.12 Dryer); This machine guarantees 100% drying of the materials that are introduced through precise temperature adjustments and controls.

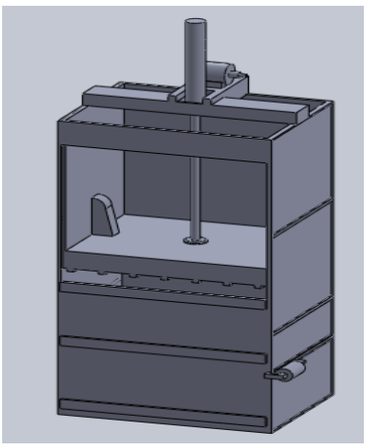
Figure 3.12 Dryer



Source: Own elaboration, SolidWorks 2012

The pressing process is carried out in a hydraulic compactor press which compresses or compacts waste materials, reducing the volume of materials providing more space for additional waste material by compacting it until the moment of collection (Figure 3.13 Compactor).

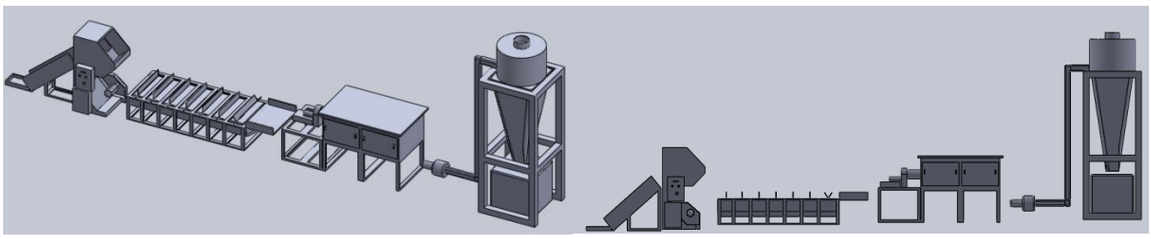
Figure 3.13 Compactor



Source: Own elaboration, SolidWorks 2012

The recycling plant model (Figure 3.14 Abstract of recycling production line) for the processing of potential MSW allows the continuous production of waste originated by the inhabitants of the municipalities of Xicotepec and Huauchinango.

Figure 3.14 Abstract of recycling production line



Source: Own elaboration, SolidWorks 2012

The results obtained and described above allow us to compare the hypotheses raised; In reference to Hypothesis 1, it is concluded that the opening of a recycling plant will significantly reduce the existence of products derived from PET, cardboard and paper in the environment, since the population will be able to count on a way to contribute to the environment and receive in return an economic remuneration. Regarding Hypothesis 2, the study and analysis of the value chain through the VSM, for the opening of a recycling plant effectively provided us with the necessary tools to build a prototype, because all the operations involved in each line of processing, and the appropriate machinery for these was identified.

3.9 Conclusions

Fulfilling the objectives set at the beginning of this research and following the suggested methodology, a study of the value chain of the PET, cardboard and paper recycling process was carried out, in which the operations, machinery, and client suppliers that comprise it were identified. The potential RSU for the recycling process was determined, a projection was made to visualize the number of kilograms that are generated and are daily, in the same way the inhabitants of the two municipalities were involved through the application of a survey which was a guideline for determine the acceptance or rejection of the project; Subsequently, the optimal prototype was designed in SolidWorks technological software. What was described above allowed us to assess the proposal to open a recycling plant in the Sierra Norte of the State of Puebla. The analysis presented is relevant, because it will guarantee a sustainable consumption and production modality through recycling; supporting the fulfillment of Sustainable Development Goal number 12 of the 2030 Agenda, the establishment of the recycling plant to serve the municipalities of Huauchinango and Xicotepec will promote the efficient use of MSW; The correct application of the designed production lines will contribute to the achievement of the municipal development plans that derive from the reduction of polluting sources for the environment, reducing the main problem of the effects produced by the consumption of products with PET, cardboard and paper, having economic, social but mainly environmental impacts.

3.10 Acknowledgments

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