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Eco-parks: A proposal for the collection, reuse, recycling and disposal of waste in emerging cities, using a circular economy framework

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Abstract In emerging cities, uncontrolled micro-dumps have been detected in the streets, gutters, and plots and even in protected natural areas. In these places, debris, old appliances and all kinds of urban waste can be found. In recent years, these uncontrolled outbreaks of waste have multiplied mainly due to two causes: a significant increase in the generation of urban waste, mainly construction/demolition, and white and grey lines; and, the lack of adequate facilities to deposit this type of waste. Numerous problems consequently arise, among them the negative visual impact, surface and underground water pollution, air emissions, bad odours, and the appearance of disease vectors such as rodents and insects; there is also a risk of explosion and fire. Such waste also represents a considerable expense for public administrations due to the high cleaning and disposal costs at micro-dump sites. In the mid-1990s, facilities known as eco-parks or transfer centres appeared as a solution to this problem. Our research therefore proposes the construction of eco-parks on the outskirts of emerging cities. To succeed, such eco-parks must meet several requirements, such as being conveniently located, and providing a good service.

Keywords Circular Economy · Consumption · Environmental Externality · Production · Sustainable Development · Recycle of Waste · Natural Resource.

1 Introduction

The Municipality of Guayaquil, Ecuador, owns and manages a solid waste landfill called Las Iguanas, which is privately operated and has received domestic and commercial waste from the city of Guayaquil and its surroundings since 1994. This site accepts approximately 850,000 tons of annual household waste. With an extension plan for 2021, the site is expected to contain approximately 23 million tons of waste by the time it reaches the proposed closing date. The unsorted waste arrives at Las Iguanas by lorry from the Vachagnon Consortium, and later from the Puerto Limpio Company. It is known that waste has different degradation rates. Some examples include: (i) orange and banana peels -two years; (ii) cigarette butts and wool socks -1 to 5 years; (iii) plastic covers -10 to 20 years; (iv) nylon fibres 30 to 40 years; (v) tanned leather up to 50 years; (vi) cans up to 50 years; (vii) aluminium cans and lids -80 to 100 years; (viii) glass bottles one million years; and, (ix) plastic bottles –undefined time span.

Municipal solid waste (MSW) collection and disposal is an extensively studied public service offered by local authorities, and is driven by three main factors: complexity, cost, and environmental concerns about MSW management (1). There are two environmentally friendly strategies for dealing with MSW: waste reduction, and recycling through waste separation (2). The prevention, recycling, and reuse of waste

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is the focus of the European Commissions strategy (3) for waste management and is one of the more common methods used to implement the circular economy concept at a regional scale (4). In addition, the United Nations (5) 2030 Agenda for Sustainable Development confirms the need for a substantial global reduction of waste.

Waste management firms performance, which is usually measured in terms of municipal waste production, the rate of recycling, or cost efficiency, is influenced by: the demographic and socio-economic characteristics of the population being served, examples are: Mazzanti and Zoboli (6); Sidique et al. (7); Abbott et al. (8); Czajkowski et al. (9); geographical and structural features, examples are Mazzanti and Nicolli (10); operational features, examples are: Guerrini et al. (11), method adopted, examples are: Starr and Nicolson (12) and Alhumoud Jasem (13); maturity reached, examples are: (Sidique et al. (7); Abbott et al. (8); Guerrini et al. (11)); public or private operation, examples are: (Bel and Fageda (14)); and, government characteristics, examples are: Zafra-Gómes et al. (15), Gaeta et al. (16), Bel and Fageda (17) and Plata-Díaz et al. (18).

Since eco-parks can help to improve the conditions for the final disposal of waste in Guayaquil, we propose clean points in the city. These are receiving facilities for domestic waste that, due to its characteristics or dimensions, cannot be managed by the conventional collection of urban waste and should not be deposited in dedicated containers on public roads. The collection system is passive, as private vehicles are used to convey the waste to specific containers.

All these different types of waste affect the quality of the biogas generated by anaerobic processes, and therefore its potential electricity generation. Biogas is a combustible gas generated in natural media or in specific devices, by the biodegradation reactions of organic matter through the action of microorganisms (methane gene bacteria), in the absence of oxygen (that is, in an anaerobic environment). This gas has been called swamp gas, since biodegradation occurs. The production of biogas by anaerobic decomposition is considered useful for treating biodegradable waste, since it produces a fuel of value, in addition to generating an effluent that can be applied as a soil conditioner or generic fertilizer. The result is a mixture of methane (CH_4) in a proportion ranging from 40-70% and carbon dioxide 40% to 70% and carbon dioxide (CO_2), which contains small proportions of other gases such as hydrogen (H_2), nitrogen (N_2), oxygen (O_2) and hydrogen sulphide (H_2S), among others. Biogas has an average calorific value between 18.8 to 23.4 mega joules per m, and can be used to produce electricity through turbines or gas-generating plants, for ovens, dryers, and boilers, or other gas combustion systems which have been properly adapted for this purpose.

In Ecuador, there are no biogas projects in power generation due to a lack of knowledge among local authorities. However, in previous years pre-feasibility studies and gas pumping tests were carried out in the Las Iguanas (Guayaquil) and Pichacay (Cuenca) landfills in March and April 2007, respectively. Additionally, the evaluation reports covered three sites, Chabay (Azogues), El Valle (Cuenca), and Loja. Biogas is generated by the decomposition of solid waste at a final disposal site, and can be recovered under the operation of a biogas collection system built on the site. In many places, there are areas where gas cannot easily be extracted, including areas: (i) completed but not covered; (ii) designated to accept the discharge of waste; (iii) where there is intensive movement of vehicles; (iv) with high slopes (preventing access to drilling equipment); and, (v) of old waste.

1.1 Eco-park concept

An eco-park or clean point is a centre designed and built to collect, separate and select specific waste, and then recycle materials and/or compost organic matter. Eco-parks are located on the periphery of cities, and have been created with the aim of serving citizens as voluntary contribution to the selective collection of waste. In general, an eco-park consists of a number of containers for particular types of waste: glass containers, flat glass, cardboard boxes and packaging, paper/cardboard, used clothing, metals, aluminium, stainless steel, large-capacity plastic containers, plastic bottles, furniture, wood and pruning remains, doors/frames, rubble, washing machines, refrigerators, appliances, mattresses, bed bases, used vegetable and mineral oil, batteries, oil filters, car batteries, containers of toxic/hazardous materials, paint and solvent containers, aerosols, medicines, radiographs, fluorescent tubes, computer screens and televisions, light bulbs, and others.

In Ecuador, there has been no development of these projects due to the lack of planning by the authorities and no information on the better handling of waste. It should be noted that in the city of Cuenca, an eco-park was built in Valle parish (Cochabamba sector) in what was previously a landfill. The construction of this site arose after the decision of the Municipality of Cuenca and the Municipal Cleaning Company (EMAC) to develop a project to replace the old municipal dump, which has been receiving solid waste for twenty two years. The site was built in three stages with financial support from the European Union, through the Municipality of Arezza (Italy). In the last stage, it improves the equipment of the composting plant, in which six tons of humus or earthworm fertilizer is produced every three months. In addition, a loader is to be installed that will transfer to a hopper three tons of organic garbage from municipal markets; organic and inorganic materials are separated and mixed with the earth, which finally produces twelve tons of humus. Therefore, the waste management process is conceived as an opportunity to educate the population about waste processes and the potential consequences for the environment, but also to recreational activities. Currently, four hundred tons of garbage is collected daily in Cuenca.

With regard to solid waste management and, specifically, final disposal in sanitary landfills (garbage dumps), the potential for reducing emissions generated in the short term is directly related to the availability of sanitary landfills. However, currently this is restricted to a minimum of municipalities with this infrastructure for final disposal. In addition to the three largest cities in the country, there are five cities with more than 15,000 inhabitants and landfills that could quickly benefit from carbon incentives through the Clean Development Mechanism (CDM). Moreover, the national municipal database shows that around forty seven cities with more than 15,000 inhabitants do not have sanitary landfills at all, and final disposal is carried out in open-air dumps without control of either liquid or gaseous emissions. The limited management capacity of the municipalities has been identified as an important barrier to the use of the CDM in this sector, because the municipalities lack adequate tariff systems and little investment is available for final disposal waste infrastructure.

Rubbish in Guayaquil is a health, social, and ecological problem for all sectors of the population. The basic elements in the treatment of rubbish are prevention, processing, and disposal, which are processes that represent an enormous quantitative and qualitative effort for the administration. Thus, the city has had serious problems from colonial times until recently, and before the 1990s the city had the unpleasant title of 'The Calcutta of America'.

Throughout 1992 the city of Guayaquil generated almost 1,000 tons of waste, 20 metric tons of biomedical waste, and 140 tons of waste from the construction sector; by this time, there were enough failures in the waste collection system that only 10% of the approximately 1,000 tons were collected, of which only a fraction was deposited in the San Eduardo Hill landfill. This landfill was also the disposal site for fifty years of plastic waste, tyres, lead and heavy materials, residual sediments, pesticides, and others, and at that time it caused epidemics and diseases. Also at that time, 140 metric tons of construction waste were generated and thrown into illegal and/or empty sites, flower beds, suburban roads, and other places, such as the El Estero Salado salt water stream. At the beginning of Vachagnon operations, in 1994, 1,800 tons of waste were collected daily, under a contract that lasted about sixteen years by the Puerto Limpio Company. In its current reports, the company notes that Guayaquil generates 3,000 tons of waste daily.

Recycling is one alternative which can reduce the volume of solid waste by reusing discarded materials still suitable for manufacturing other products, or remanufacturing them. Good examples of recyclable materials are metals, glass, plastic, paper, or batteries. Unlike recycling, reuse is any operation in which the container is designed to perform a minimum number of circuits, rotations or uses throughout its lifecycle, and is refilled or reused for the same purpose for which it was designed. There are many reasons to recycle, such as those resources are saved, pollution is avoided, the material's life is extended, even with different uses, energy is saved, and deforestation is avoided. Moreover, 80% of the space occupied by waste is reduced by becoming garbage, the payment of taxes for garbage collection can be reduced, and employment and wealth are generated. Most waste is reusable and recyclable, but the problem is that when mixed it becomes rubbish. One solution to this is to separate the waste for recycling. It must also be taken into account that it is practically impossible for the waste to disappear, as some materials need time to deteriorate in nature, as noted earlier.

Nowadays, diverse materials are recycled, the most common being paper, glass and packaging but also mobiles and batteries, as they contain elements that are highly polluting, such as mercury (button batteries), zinc (traditional batteries), nickel, and cadmium (in computers and mobile phones) or manganese (appliance batteries). The recycling of consumables linked to computer science, such as ink or toner cartridges for laser printers, and the computer equipment itself, is also booming. Finally, composting is nature's way of recycling its own waste, controlled by the decomposition of organic materials through the action of various microorganisms and invertebrates. More than 50% of household waste can be recycled with this method.

1.2 Eco-park location

Despite the current efforts from the Municipality, the culture of waste reuse in homes is not prevalent. Moreover, the Puerto Limpio consortium has no competence in the differentiated management of waste. In this regard, the more successful Dutch projects have mostly been initiated by companies with the financial and advisory support of local and regional government. Since the introduction of the industrial ecology concept by Frosch and Gallopoulos (19), and the apparent success of the Kalundborg Industrial Symbiosis project (Jacobsen, (20)), attention to planned eco-industrial park development projects has grown globally (Heeres et al. (21)). Among Dutch cities, Rotterdam (Bing (22)) stands out, where a park built on a floating platform made with plastics collected from the water was inaugurated. It is remarkable that Limburg (Milios (23)) has reached recycling levels as high as 60% of MSW, recycling 412 000 tonnes in 2008, whereas in Guayaquil 100% of the waste collected by the Puerto Limpio consortium goes directly to the Las Iguanas landfill, and classifying and reusing waste is not within the consortiums contractual obligations. However, as an environmental responsibility initiative, Puerto Limpio promotes campaigns for citizens to classify their waste and only has one that cannot be reused for collection. It is estimated that, of the 3,800 tons per day of waste produced in the city, 85% can be recycled. Currently, the Municipality is tendering the contract for a new company for the collection and disposal of waste, and the firms that comprise Puerto Limpio (Valango, and Hidalgo and Hidalgo) are competing separately, having formed new ties. It is necessary that the new contract includes a differentiated collection system. According to data from the National Institute of Statistics and Censuses INEC (24), nationally in Ecuador 58.54% of households do not classify waste. From 2014 to 2016, the main reason for this was due to the lack of specific containers or recycling centres. The INEC report also shows that in 2016 the number of households mixing batteries with their rubbish was 79.53%. At the national level, the percentage of households generating hazardous waste in their general rubbish, by type of waste, was: pharmaceutical (87.92%), electrical or electronic (70.43%), and, oil and/or grease from kitchens (54.36%). The Municipality of Guayaquil is considering other places for the new landfill, on the waste passing to the Papagayo.

2 Design of Eco-park Facilities

With this type of collection centre, citizens take selected waste to facilities with containers ready to collect it, in addition to a collection system provided by the eco-park itself. There are different types of enclosures, depending on the size of the population they serve. Based on other eco-parks built in different parts, this facility has collection containers that we believe are convenient, such as for the collection of refrigerators and sorted appliances. In addition to these items in the eco-parks, the following are also collected: oils, cells, batteries, fluorescent, cardboard and paper, rods, textiles, furniture, debris (from construction work), gardening, glass, metals, plastics and wood. For users, once inside, they pass through a control booth, at which the car is weighed and then ascends a ramp.

The site has a series of top opening metal containers (for the users convenience) into which waste can be thrown, and then the car leaves by another ramp. In the case of collection lorries, it is expected that these will be equipped with small tractors that facilitate the loading and unloading of containers. When choosing between several placement options, the cost of intrinsic and annexed works is a very important factor to consider, such as: (i) placing the operator booth at the entrance; (ii) exterior fencing of the enclosure; (iii) collecting and evacuating wastewater; (iv) access and internal circulation; (v) comfort for

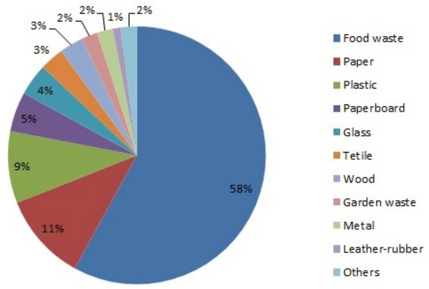

Fig. 1 Waste type composition (from (25))

staff; (vi) weighing installation; (vii) communications lines; (viii) fire protection equipment; (ix) lighting installation; and, (x) drinking water pipes. The proposed collection is carried out in different circuits: (a) mass waste collection at the sidewalk level by container; (b) collection in contribution areas, such as paper, cardboard, and glass; and, (c) special collection waste: old furniture and fixtures via a free door-to-door service. The waste composition of the Iguanas Landfill by type is shown in Figure 1.

Regarding the use of the facilities throughout the week, it is expected that the eco-park will be used from Monday to Friday from 8:00 a.m. to 5:00 p.m. so that it serves users on weekdays, with possible future schedules on Saturdays. It is planned to analyse the demand that the eco-park will have in the future.

2.1 Containers

There are two sizes of containers, small and large. The small ones have a low-density of approximately 2.25 m^3 and are similar to those installed in the four-wheeled mass collection; the large high density open containers are 20 m^3 and have great capacity for bulky waste and debris, but require a lorry to remove the waste. The lorry has a lift system to facilitate the approach to the container, and hooks chains to the container to remove the waste because of the manoeuvring space it has. For the low-density containers, lorries with a fixed box system are sufficient. The advantage of these is that they remove the contents of the container and but not the entire container, as in the previous case.

2.2 Pickup Frequency

Table 1 shows the different containers that are going to be placed in the installation according to the discarded material, and based on the operation of the installation of the Clean Points. It also shows the number of containers and the frequency of collection per year of recyclable materials.

Table 1 Types of Waste

Type of Waste	Tons/year	Number of containers/year	Pickup frequency
Paper	11,443	954	Every 5 days
Paperboard	5,202	434	Every 10 days
Glass	4,161	347	Each 15 days
Textile	3,121	260	Each 15 days

As this type of recyclable waste represents 2% of the total waste in the city, a special area is needed for its deposit. Space is required, according to the data obtained on the frequency of final disposal, because it varies according to demand. It has been taken into account that inside both the small and large containers there is a density of approximately 600 kg/m^3; therefore large capacity containers deposit up to 12,000 kg and low capacity up to 1,350 kg. Once the number of containers is known, the collection frequency is simply arrived at by dividing the number of days of the year by the number of containers that are filled by a certain waste type annually. The site will also have a classroom, in which seminars and workshops on recycling and the environment will be held, and a recycling workshop in which different ways of making use of recyclable materials will be demonstrated.

3 Circular economy framework: Waste becomes a value resource

There are many products that we discard as having no value; however, many can be reused instead of being left to accumulate and decompose in a landfill. Even though all material is considered biodegradable, much of it takes a significant amount of time to decompose. Under optimal conditions, the decomposition (biodegradation) is in the presence of air (oxygen), sunlight, and humidity. Fortunately, glass is a 100% recyclable material, i.e. from a used container, a new one can be manufactured with the same characteristics as the original. The advantages of glass recycling are numerous: used glass considerably reduces the energy required for its manufacture; there is less erosion caused by searching and extracting raw materials; the carbon footprint is reduced. Another advantage that is difficult to quantify but no less important is that recycling is better for the environment than discarding, for example, in the past, thousands of tons of wood ended up in landfills, but its recovery can prevent the cutting down of millions of trees. Pallets and other wood remains are nowadays moved to an eco-park, and from there to treatment plants where the wood is destined for the chipboard, energy production, and compost manufacturing sector. With furniture, the situation has changed; although once inherited, today the trend is to replace old furniture with new.

3.1 Reusing and recycling furniture

In 2009, the United States Environmental Protection Agency (26)reported that furniture accounted for 9.8 million tons (4.1 percent) of household waste. The product group of furniture comprises free-standing or built-in units, whose primary function is to be used for the storage, placement or hanging of items and/or to provide surfaces where users can rest, sit, eat, study or work, either indoors or out. Mattresses are included within the scope (27)), as they are a main source of contamination from formaldehyde (Danish Environmental Protection Agency (28)), a highly carcinogenic substance. Moreover, the combustion of PVC used in upholstery produces dioxins (Kallonen et al.(29)), which are also carcinogenic. All these products ended up in uncontrolled landfalls where they produced not only varying degrees of pollution but also a very significant visual and landscape impact. Furniture in good condition that allows its restoration should be donated to non-profit organizations i.e. for the rehabilitation of drug addicts, associations of physically and psychically disabled, municipal schools, and workshops where the furniture itself can be restored.

3.2 Reusing and recycling paper

The paper industry is also currently one of the most polluting, as it uses semi-chemical pulps, chlorine, and other auxiliary products to treat paper (Martin et al. (30)). Recycled paper is achieved using paper waste as raw material. It is crushed and then has different purification systems applied, before being bleached (with chemicals such as chlorine), dried, and cut (Tenenbaum et al. (31)). Studies demonstrate potential synergies between energy, waste, and water flows within a hypothetical circularity mode, where the circular economy concept is applied to enhance material exchange for the forest, pulp, and paper industries (Mabee et al. (32)) Items that contain metallic elements to a greater or lesser degree can also be recycled and converted to scrap (Roman and Puckett (33)), after removing non-recoverable products. The clean scrap is destined for smelting, while scrap that carries other components (plastics, insulating materials in refrigerators, etc.) is first subjected to a separation process to avoid contaminating other processes (e.g. lead in television cathode tubes, CFCs in refrigerants in refrigerators, heavy metals in computers and mobiles, and others). In addition, lately it has become possible to donate computers to non-profit organizations (NGO) that operate independently of government, for use in their projects e.g. the NGO titled "New Technologies for Africa" has already sent dozens of computers (collected free of charge throughout Spain) to projects in the Cameroon, Mauritania, Burkina Faso, and Morocco, where computer rooms have been installed in schools and various educational centres.

As mention before, recycling processes are the methods by which recyclable and non-recyclable materials are separated; in turn, recyclable materials are separated according to their physical characteristics for later reuse. After being separated and classified the used products are subjected to different processes for the creation of new products with the same characteristics as the originals. In this way, the matter recovery process is accelerated, which in the short term means lower environmental deterioration, as not much matter and energy will be spent on creating new products.

Paper recycling is a recovery process already used to transform old paper into new paper products (Pivnenko et al. (34)). There are three categories of paper that can be used as raw material for recycled paper: ground, pre-consumption waste, and post-consumer waste. Ground papers are cuttings and pieces from paper manufacturing that are recycled internally in a paper mill. Pre-consumer waste is material that has already passed through the paper mill, and been rejected before being prepared for consumption. Post-consumer waste is used paper material that the consumer rejects, such as old magazines or newspapers, office supplies, and telephone directories.

A common industrial paper recycling process is in paper mills, in which paper bales are loaded on a conveyor belt that pours them into a large tank called a disintegrator (pulpier). Inside this, water and various chemicals break up the material into small strips of cellulose, which are the vegetable fibres that comprise the paper. The resulting pulp goes into the sieving phase, where the aqueous mixture runs through a series of treatment plants designed to separate debris and other contaminants. Next, the pulp is thoroughly cleaned in large, cone-shaped rotating tubes, which drive the heavier elements (such as the staples, for example) to the side and out, while the lighter contaminants accumulate in the centre for separation. The pulp is then poured into a tinting centre. Paper mills often use two stages in this process: first, the pulp is subjected to a soap wash to remove the smallest remains of the ink, and then, in the second stage, called tinting by flotation, sticky substances such as adhesives are removed. The process is carried out in a large tub called a flotation cell, inside which the pulp is mixed with small air bubbles and detergent reagents called surfactants (Li et al. (35)). These release the stickers from the paper, and the air bubbles drag them to the surface of the foaming liquid, where large networks remove the residue thus formed. There is a great deal of residual matter, as ink, glues, and fibres that are too small to be reused make up almost a third of the paper that is sent for recycling. In the next stage, called refining, the paste mixture is beaten until it becomes the starting material to make paper. Large blenders break up cellulose into thin, individual strips. The process causes the fibres to swell, reaching the ideal texture for papermaking. Chemicals extract pulp dyes and, if desired, it can then be bleached with hydrogen peroxide, ready to turn into paper.

New cellulose fibres (called virgin fibre) can be added to the pulp, or it can be used as it is. In either case, the pulp is mixed with water in the proportion of 99.5% water, and injected into the papermaking machinery. The first stop is at the machine head, a gigantic metal box that contains a dispenser where the liquid mixture is sprayed and deposited on a wide mesh fabric located on a moving conveyor belt. While the water drips through the mesh and the pulp dries, the cellulose fibres begin to unite to form a leaf. Felt-coated rollers press the water from the sheet (called cloth) as it passes. The fabric then circulates through hot metal rollers that dry it, and it can also be passed through additional baths to make glossy paper. The resulting paper is rolled up in a gigantic roll 9 m wide weighing almost 25 tons, but can be divided with a special cutter into smaller rolls for later shipment to the various printing plants.

Some types of cardboard are used to make packaging and containers, basically boxes of various types. The top layer can receive a different finish, called stucco (or render) that gives it greater visibility. According to the raw material used in its manufacture, four types of cardboard can be distinguished: (i) solid bleached board (SBB) or solid bleached sulphate (SBS) is manufactured with bleached chemical paste in the inner layers and stucco layers on the top and back sides. It is used for cosmetic, pharmaceutical, and other luxury packaging; (ii) solid unbleached board (SUB) is more resistant than SBB and is used for beverage packaging (bottle and can groupings); (iii) folding boxboard, also referred to as FBB, is manufactured with several layers of mechanical pulp between layers of chemical pulp. It is used in frozen and refrigerated food packaging of desserts; and, (iv) white-lined chipboard, also referred to as WLC, GD, or GT, is manufactured with recovered fibres and consists of many layers of various types of fibre. It is used for cereal containers, toys, and shoes. A corrugated box was first used for packaging glass and pottery containers and is the largest unit source of waste paper for recycling. The future of corrugated cardboard recycling is very promising.

Certain pollutants can limit the marketing of old cardboard boxes. Buyers frequently cite contaminants in their proposals as specifically prohibited, including: (i) satin cartons or waxes; (ii) any carton that has contained an agricultural product, meat or poultry; (iii) any food, packaged or non-packaged; (iv) any plastic or plastic foam (Styrofoam); (v) bottles or bottle holders; (vi) posters and other advertising materials; (vii) dirt, floor sweeps, wood, metal, and organic waste; (viii) any type of tape, except adhesive Kraft paper tape or water soluble forms; and, (ix) magazines, newspapers, books, cards, and aluminium foil. Most old cardboard boxes that can be easily obtained for recycling come from grocery stores and other consumer goods, and from the distribution systems that supply these establishments. Corrugated cardboard remains the most effective container for transporting goods to market.

3.3 Reusing and recycling plastic

Radiographs are plastic products (usually polyethylene terephthalate or PET), whose main pollutant component is silver. For this reason, they cannot be thrown into the bin but must be deposited at clean points for later recycling. Khunprasert et al. (36) showed that an oxalic acid solution at 5% (w/v) provided the best leaching conditions at 100^{o}C for 20 min. This achieved 100% silver leaching from the films. The obtained silver was in its metal form and ready for ingot production. With the sale of this silver, a non-profit organization receives important funds for projects around the world. In addition, it should be noted that silver is a heavy metal and, once released, and in certain concentrations, can be very toxic and seriously harm the environment.

Currently, there are hundreds of types of plastic derived from petroleum in our home, in containers of cleaning products, bags, and toys, among other things. Plastics are reusable materials because they are durable, resistant, and washable. The plastic material has several points in its favour: it is economical, light, unbreakable, very durable, and even has good electrical and acoustic insulation properties. However, its recycling has many drawbacks, and each of the steps to complete the process greatly increases the price of the product. The different classes of plastics are classified according to resin, and are mostly: PET, low-pressure polyethylene (high density) HDPE (LDPE), high-pressure polyethylene (low density) LDPE (HDPE), polyvinyl chloride (PVC), reusable polypropylene (PP), polystyrene (PS), and a seventh category called 'others'. This separation is due to the fact that the resins that make up each of the plastic categories are thermodynamically incompatible with each other, we must add the work of separating the covers, which are generally not made of the same material. This is not the only drawback; in the recycling process, the plastic loses some of its original properties, so there is a need to add a series of additives to recover its properties.

Glass, however, is easily recoverable dues to its characteristics. A glass container is 100% recyclable from a used container i.e. a new one can be manufactured and have the same characteristics. Glass is a silicate that melts at 1,200 degrees. It consists essentially of silica (coming mainly from quartz), accompanied by limestone and other materials that give it different colours. From the point of view of its application, glass is classified as industrial and domestic. Industrial glass is used for the storage of chemical and biological products, flat glass in windows, armoured glass, fibre optics, and light bulbs, etc. Domestic glass is used for food products (preserves, wines, yoghurt, etc.), and generally this is the glass that citizens deposit in recycling containers (Butler and Hooper (37)). From the point of view of colour the most used are (i) green. Used massively in bottles of wine, cava, spirits and beer, although in smaller quantity in the latter, (ii) the clear. Used in soft drinks, beers, medicines, perfumery and food in general, (iii) the extra clear. Used essentially in mineral waters, jars and decoration bottles, and, (iv) the opaque or amber. Applied in beers and some laboratory bottles

From the point of view of colour, the most used are: (i) green, in bottles of wine, cava, spirits and beer, although in smaller quantities in the latter; (ii) clear, in soft drinks, beers, medicines, perfumery, and food in general; (iii) extra clear, used in mineral water bottles, jars, and decoration bottles; and, (iv) opaque or amber, in beer bottles and some laboratory bottles. The recycling of glass containers saves energy but not a significant quantity compared to reuse. The energy saved is about 13% of the energy required to make glass containers from virgin raw materials, while the total energy consumed in processing glass containers with no post-consumer recycling is approximately 9.4 x 106 Btu plus 484 kWh per ton of containers delivered (per net ton) (Gaines and Mintz (38)). In addition, glass makes up a relatively small fraction of waste (6.5% by weight) and is inert; it is also denser than most other products in MSW and therefore only comprises 2.2% of MSW by volume.

While glass bottles can be reused several times, after this they are recycled. There is no technological diversity for its treatment. Crushed glass enters a top screen, over which vacuum hoods are positioned. These remove light materials such as paper, plastic and aluminium caps. Glass which is too large to pass through the first screen (with a diameter greater than 28 mm) is directed back to the pre-manual picking stage. The glass then drops through the top screen and lands on a second, finer, screen. Fragments with a diameter of less than 8 mm drop through the screen, and the remainder pass back to the manual picking stage (Consortium for automotive recycling (39)). Essentially this process consists of separating the extra elements that usually accompany glass (paper, plastics, corks, stones, metals, porcelain, and others). The separation is done manually and/or with specific equipment: fixed magnets for iron, cyclones for paper and plastic, and a non-ferrous metal detector uses mechanical impulses, with ceramic and stone sensors. Currently, it is already being operated with laser equipment to separate all impurities. In addition to the extraction of foreign elements, the glass is initially crushed, washed, and screened. The objective of all these treatments is to improve the quality of the glass to achieve high performance in the baking ovens. The first step in the glass recycling process is cleaning.

Although the glass is of different colours, this does not influence the production of new containers, since the coloured glass is treated with bleach. That is why white is important, as it is purer and minimizes the use of bleach. In the first place, the bulk of the plastic in the containers is removed, and then the glass is washed in a "washing machine" to remove dirt or grease. Once clean, it goes through different sieves and hammers and is ground to achieve the necessary granulometry. The next step is through a special container with magnets, to extract the vestiges of metal. Once this process is finished, the glass is melted in an oven at 1,600^{o}C in the proportion of 50% recycled glass and 50% virgin matter, to achieve new glass containers. The whole process lasts 24 hours.

The industrial glass recycling process varies according to the shape and colour. Despite this difference, glass suffers little from quality loss during the recycling process. For all types, less energy is required for recycling than for producing it from raw materials, which is the main benefit. With the following types of technologies, a modern and profitable glass recycling installation for container glass is expected:

- Dirty glass hopper. In the initial part of the process, the glass is deposited by forklift. Dirty glass hoppers can store approximately 26 tons of glass each, and each has a clam gate and a vibrator with an intensity selector to position the flow of dirty glass as required, to obtain the correct quality and quantity of washed glass.
- Vibrating screen. This is a perforated steel plate that must be constantly cleaned by the person in this area; it also removes easily detectable rubbish (cardboard, plastic, and wood, etc.). Liquid filled or closed containers (carbonated soft drinks, beer, etc.) should not be broken manually, but removed to avoid accidents should they explode. The materials that pass through the mesh fall inside the sieve box, where they are subsequently carried by a worm or helical conveyor to an elevator.
- The belt that feeds the drum. The glass is fed into the drum on an inclined band, which has a magnetic pulley at the end, and which eliminates magnetic contaminants. These are sent by a short band to the band that feeds the elevator, and in addition there is a fan located in the discharge of the band inclined to the mouth of the washing drum, to eliminate paper and light material.
- Drum. In the drum the washing of the dirty glass is carried out. It has an inner spiral shape that: a) serves to transport the glass towards the matting (wide metal band); b) helps to mix the glass efficiently with the wash water it receives against the current; c) removes the edges in the glass when the drum is moving; the drum rotates on its axis with the help of wheels. The wash water is cleaned and recirculated by the water treatment plant.
- Mat band. The mat is a rotating metal band approximately 2.30 m wide, at a distance of approximately 10 m. At this point, contaminants that could not be removed in the previous steps are manually

penetrated. It is the responsibility of workers in this area to manually separate any type of contaminant that is not glass (for crystalline glass, glass of another colour must be separated). The removed material is carried by a worm or helical conveyor to the belt that feeds the elevator.
– Vibrating sieve. Washed glass is fed to the sieve by the mat, which is a vibrating conveyor that also functions as a size separator, passing glass of dimensions smaller than 1 inch (diameter of the plate holes) through the perforated glass plate, to the feed belt that goes to the washed glass elevator. Glass pieces with dimensions larger than 1 inch pass to the belt that feeds the impact mill.
– Impact mill. Here, glass parts larger than one inch are reduced by a set of metal pallets. The ground glass passes through a return band to the belt that feeds the washed glass elevator. The personnel placed here manually remove impurities that have not been removed in the previous steps.
– Storage hoppers. From the washed glass elevator, the ground glass passes through a strip that feeds the washed glass storage hoppers. These hoppers have a capacity of approximately 42 tons each. Sometimes a person is placed in the washed glass aerial band to remove impurities manually
– The rubbish collected in the different currents converges in the garbage feed belt to the elevator, which deposits it in the garbage hopper and then evicts it to a dump truck and hence to an appropriate place.

4 Economic Analysis

In this paper, the economic analysis is a systematic approach to examining the allocation of limited resources to achieve the objective of a sustainable eco-park in Guayaquil. To estimate the profitability of potential investments, we use net present value (NPV) as the difference between the present value of cash inflows and the present value of cash outflows over a period of time, and the internal rate of return (IRR) to estimate the profitability of potential investments. Cash flow is the net amount of cash that an entity receives and disburses during a period of time, which in our case is twenty years. Our first assumption is that the amount of waste produced per year in the city of Guayaquil is 1,095,000 tons. From this, Table 2 follows as below.

Table 2 Tons and monetary gains per type of waste

Type of Waste	Tons per Year	Tons to the Eco-park	Revenue (sales per year)
Paper	120,450	11,442.75	$343,282.50
Paperboard	54,750	5,201.25	$156,037.50
Glass	43,800	4,161.00	$249,660.00
Textile	32,850	3,120.75	$936,225.00
Sales per year			$1,685,205.00

Table 2 shows the amount in tons that it is expected will be received of each recyclable material, as well as the profits generated in the first year of operation of the eco-park. The prices converted into dollars per ton should be taken into account; this means paper and cardboard will have a profit of $30/ton, glass a profit of $60/ton, and textiles $300/ton. It is expected that the park will receive 20% of all generated waste. In addition, it should be borne in mind that to start the business, an initial investment is required, as broken down in Tables 3 and 4.

It is also necessary to consider monthly investments in terms of basic service expenses, salaries, maintenance, and others as shown in Table 5.

The expected cash flow shows an expected investment of $20 million for the construction and commissioning of the eco-park. The eco-park will be built and all the equipment purchased to begin its operation. There will be a fixed cost of $ 31,500 dollars per month used to pay fees, as well as basic services. The variable costs are approximately 20% of the income and are generated from the sales of the material. As a conclusion, the eco-park will be completely sustainable from the fifth year of operation because of the expected growth of 11% per year in the income of recyclable materials. The net present value is $ 502,439.89, and the internal rate of return is 15%, which means the eco-park will be a productive business in the following years.

Table 3 Investment

Edification	$3,750,282.00
Purchase of recycled materials	$4,000,000.00
Machinery	$150,000.00
Cellar	$ 250,000.00
Trucks	$200,000,00
Design studios	$100,000,00
Furnished facilities	$100,000.00
Expenses (amortizations)	$450,000.00
Total Investment	$ 9,000,000.00

Table 4 Investment breakdown

Workforce (30%)	$1,125,000.00
Materials (70 %)	$2,625,000.00
Purchase item of recycled materials	
Recycled materials	$4,000,000.00
Machinery items	
Five small tractors	$150,000.00
Truck Items	
Four Trucks	$200,000.00
Design studio item	
Opinions, project sustainability, environmental impact studies	$100,000.00
Furnished item of facilities	
Purchase of furniture, computers, fridge, and others	$100,000.00
Expenditure item	
Total inversion	($9,000,000)
Number of years (20)	$ 450.000,00
Warehouse item	
Collection centre in the city	$250,000.00

Table 5 Fixed monthly and annual costs

Fixed monthly costs Value	
Wages and salaries	$10,000.00
Phone	$ 100.00
Water	$ 100.00
Electricity	$ 400.00
Insurance	$ 2,000.00
Stationery	$ 400.00
Materials and supplies	$ 1,000.00
Vehicle Maintenance	$8,000.00
Gas	$1,000.00
Mobilization Expenses	$1,000.00
Total	$24,000.00
Annual fixed costs	$288,000.00

5 Conclusions

The general theoretical literature on eco-parks in emerging countries is inconclusive on several vital questions within the circular economy discourse. The main conclusions are: (i) the project is expected to be profitable from the fifth year because the debt values will be paid in full according to the cash flow analysis. The net present value and the internal rate of return show adequate values for this type of project. However, for the eco-park project to be profitable at 20 years at 15% interest, we must collect 20% of the waste from the garbage of Guayaquil; to achieve this in the following years, an additional 11% is expected to enter the eco-park every year.

The eco-park needs the necessary equipment and facilities to carry out workshops and conferences on the environment, to promote environmental awareness among citizens. Therefore, through environmental campaigns, objects considered to be waste can be recycled and stop polluting the city. Finally, we propose additional collection centres to collect waste from people who are far from the centres, to contribute their waste in the eco-park.

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