MODULE 3: Logistics & Sorting

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1.1.2 Residue Management - Brief Introduction

How much do we generate?

We are going to start with an introductory case study:

Its aim is to explain the problem of waste in a simple way. Are we able to answer the next question?

Do we know how much waste do we generate during our life?

A person starts generating waste from the time they are born. In the first year of life, a person produces over 200 kg of waste, most of it diapers. During their life, a person will produce more than 650,000 kg of waste, garbage, toxic substances and other forms of pollution.

From those 650,000 kg a person will produce no less than 34,000 kg of domestic garbage or municipal solid waste in about 75 years. **That is 440,000 m3, equivalent to a 120 m2 apartment filled to the ceiling with garbage.**

How did we manage this problem in the past?

But how did ancient cultures manage this problem?

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A collective management for an individual problem

That is why most government agencies attempt to solve this individual problem through collective management, empowering municipalities to implement waste collection services. For a time, this solved the problem of waste piling up in the streets.

Depending on how it is implemented, the law tasks the administration closest to the citizen, generally the municipality, with this remit.

It is clear that what citizens want is the best possible service at the lowest possible cost.

This is where the problem lies: **if we are unable to explain to the public what proper waste management entails, it will be difficult to charge for this service.**

The invisible labour

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Nowadays waste management is like a black box where we just throw our bag into the contanier and magically it dissapears.

It is because of all this that **transparency and information involving waste collection are considered crucial.** The citizen leaves the garbage bag in the container, and it's taken away, so

in their view, they do not understand the complexities of the system, or even why they have to pay for it.
If the public doesn't understand the hundreds of trucks that are used, the hundreds of people who work in it, or even all the tons that are handled, it will be difficult for them to understand the cost of the service.
And why does this perception exist? Because we do not allow waste to pile up at their door. It is picked up often enough, without making a noise, that it does not create offensive odors. Residents have containers or drop-off points for their waste relatively close to their homes, containers that are clean and do not create major problems for residents.

Our role as students

So how are we going to work to improve this situation?
If I have heaps of garbage nearby and every time I open the window I smell its "aroma", the problem becomes apparent and the best solution is usually to burn it, though that turns it into a different kind of problem, one I'll see and smell from my window every day.
The goal of this section is to ascertain, from a technical point of view, what the problems are, what the market's proposed solution is, the pros and cons of the technologies available so we can take all the factors into consideration and then tailor and implement solutions.

Goals of this área

So what is our mission while talking about waste management in PackAll?
Determine the parameters that define the waste management model. Analyze the possible alternatives and their limitations, and quantify technical solutions.
In short, PROPOSE:

- **What**
- **How**
- **When**
- **With what.**

WHAT

- Define what municipal solid waste is
- Which fractions are separated.
- Where they are transported.

HOW

- What technology we use.
- How containers are distributed. Number of containers per inhabitant. (Ratios)
- Purpose IMAGE – RESULT

WHEN

- When the waste calls for it (economic)

- Maximizing the service (at all hours). (Use experience)
- Minimizing the impact on residents.
- COST - SERVICE balance.

WITH WHAT

- Determine the resources needed. Trucks and Operators.
- Include contingency solutions. (Reserves)
- Provide the service with the necessary auxiliary resources. Facilities. Organization. Control.

Residue Management - Methods of managing MSW

What is municipal solid waste? - MSW in our daily life

You just had breakfast. You didn't finish a piece of bread with butter. You were full. There are cookie crumbs on the table.
You pick it all up and put it in the can under the sink, alongside the vacuum cleaner bag you changed out and some socks that, after showering this morning, you realized had some holes in them.
There is also an empty milk bottle from breakfast, and the empty tub of butter. You have to change the bag because it's full.
- Who threw out the paper before I got a chance to read it?
- It doesn't matter. You take the bag out and then down to the container.
This is where your problem ends and ours begins.
In one day, you have produced almost a kilo of a solid mix of materials that you want to get rid of. This is what is known as garbage, or what **we in the business call Municipal Solid Waste, or MSW.**

MSW Definitions

Let's go one step at a time:
What is waste?
Some authors define **waste as a resource in the wrong place**. What for me are old-fashioned shoes could, somewhere else, be the only protection between one's feet and the ground. My leftover food can be turned into compost to fertilize farms, and my plastic drink bottle can be turned into thread to make new clothes. **The problem with waste is mainly how to get it from the person who generates it to someone who can take advantage of it to give it a second life and, moreover, do so efficiently**.
What is considered municipal waste?
That waste that is generated in **urban centers or in their areas of influence and whose management is the responsibility of government** agencies.

In summary:
we can define **waste as everything solid that its owner doesn't want, or doesn't know what to do with, and throws it away**, at which point the government is responsible for handling it.

What makes up household waste?

So far we have used municipal solid waste as an all-purpose term, without understanding what it is made of and what purposes it may have. **It is important to understand what types of materials can make it up and to design systems that can be used to sort this waste efficiently** in relation to the potential use it will have after processing.
Volume of waste generated and viability.
First of all, we have to consider what level of collection can make it viable for a company to set up production processes with the materials recovered.
In general terms, the **small amount of individual production makes** this transfer of materials between production (individual) and the consumer (company) **only viable on a group level.**

Waste treatment plants act as mining facilities that recover materials from the mines that reach them: **the higher the purity** (in terms of the materials collected separately), **the more that is recovered.**

Purpose

When planning waste collection, we have to understand what the waste collected will be used for. There are different waste management alternatives, including landfilling, incineration, recycling and composting.

The Circular Economy System Diagram - Ellen MacArthur Foundation
The Circular Economy System Diagram of the Ellen MacArthur foundation is very interesting. For more information, see https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic

Landfills

Alternatives such as landfilling **do not generate any value in terms of reintroducing waste into new production processes.** They also have a high environmental impact, but, without going into great detail:

- Would it make sense to collect waste separately if we then deposit it all in a landfill?
- The answer seems obvious: **No**. It would be more useful to collect all the materials that make it up together. This would save money, time and emissions in the collection routes.

Energy recovery, or incineration

Another alternative, such as the energy recovery of waste through incineration, recovers very little of the potential value of the waste.
This strategy is not advisable as the main alternative in the management of municipal solid waste, since, as we have seen, **it does not prioritize a short cycle within the circular economy system diagram**.
But in terms of how we should approach waste collection, in the hypothetical case that we were going to incinerate it:
- Would it make sense to collect waste separately?
- In this case, maybe so.
- But **how much would we have to sort** it?
- In that case, a separate collection system would have to be implemented for those materials that cannot be burned because they have no energy value (glass), and/or those that are of interest to protect the economy, commerce and/or in application of environmental principles.

Recycling and composting

Having analyzed the alternatives that recover the least amount of value, we will now analyze two that try to maximize the value of municipal solid waste by preparing it to be reintroduced into production cycles:
Recycling
Composting
These two methods require setting up a separate collection system that allows waste to be segregated at the source. This would maximize the flows of material that would be reintroduced into production processes.
- But what materials should we prioritize?
- Viewed externally, if we were asked this question we would say: Whatever there is more of! Quantity is a decisive element due to its impact on cost. It is cheaper, per unit, to move a lot than a little (a bus is more efficient if it carries more people).

Cost concept while talking about circular economy

We have said that it makes sense prioritizing the flow with a bigger quantity...

- But we are not just talking about quantity, we have to consider its potential, as we said before. **We have to prioritize those that can replace virgin raw materials while offering the same characteristics at a lower cost.**
Regarding this last aspect, it is important to understand the **concept of cost.** While cost in the current production system tends to be simplified as the economic cost, there are other components that should weigh in this decision - environmental cost, reputational cost, etc. To understand better this concept watch the enxt video from the Ellen macArthur Foundation
https://youtu.be/aGrcU0TPhuI
Source: Ellen MacArthur Channel in youtube
- that must also be evaluated by companies.
To promote this change, European institutions, as we will see later in this program, are implementing new legislative developments to enhance the competitiveness of recycled materials, such as minimum rates of reintroduction of recycled material into new products, and taxes per ton on virgin materials.

Composting

The main difference in deciding whether to compost or recycle is whether the waste is organic or inorganic.
In the case of the former, we will opt for composting, while if we want to maximize the value of inorganic waste, we will opt for recycling.
Composting:
Organic matter, which is the most prevalent type of household waste, has an advantage when it comes to processing it, namely it is biodegradable, and we have known for many years how to minimize its impact. It's simple, and it only takes a few months for its organic chains to degrade to gas: methane (we can use its energy) and however much CO_2 it took in over its lifetime. **In addition, the collection of organic waste through the brown container before January 2024 is an "unavoidable and inevitable" requirement of the European Union for all its member states.**
There is a very complete report from the European Environment Agency about the challenges and opportunities thta bio-waste represents.
At present, t**hese events are giving rise to the appearance of a large amount of new compostable waste,** not only the organic matter we are all familiar with (food waste, coffee grounds, etc.), but also **packaging made with compostable bioplastics, such as bags made from potato starch or single-use food service items made with sugar cane.**
This waste must be properly sorted by the user and deposited in the container set aside for organic matter so it can be properly composted. Until now, since it was not mandatory, a large amount of this material was discarded with the “rest” fraction, where it could come into contact with hazardous waste that would prevent its recovery.

Recycling

Definition:
First, we need to understand what recycling is: We can define it as a p**rocess whose goal is to convert waste into new products or raw material for later use**.
It is important to understand recycling as one of the alternatives within the waste hierarchy when a product comes to the end of its life.
Learn more about this concept at https://ec.europa.eu/environment/green-growth/waste-prevention-and-management/index_en.htm and associate it with the alternatives we have been discussing.
But as regards this program, we will talk about **managing waste that has already been generated**, and how to turn it into raw materials again.
In the next lesson we are going to analyze some of the most important characteristics of the different material flows that are found in municipal solid waste.

Residue Management - Material Flows in Municipal Solid Waste

Material Flows in Municipal Solid Waste – Introduction

During this lesson we are going to analyze some of the most important characteristics of the different material flows that are found in municipal solid waste.
We will analyze:

- Paper and cardboard
- Glass
- Organic
- Light packaging

Paper and cardboard

Characteristics:
- They can be collected together because they share the same fate: to become pulp to be reused in the paper industry.
- It is a conglomerate of materials with a **density of 50 to 100 kg/m^3** (in a container).
- To achieve this density, **containers have to be designed with small openings that make it necessary to fold the cardboard before depositing it**. This increases the density and makes the collection more efficient.
- This waste type does not give off any odors, so its pick-up can be delayed until the container is full.

How it is generated:
- Household production ranges from 15 to 25 kg per inhabitant and year in Spain.

- Commercially: high production, widespread use in packaging. Due to the volume it takes up, its storage is problematic, and if the production volume is not high enough to warrant a waste processor (small business), it usually ends up with household waste.
- Administrations: Generators of large volumes of paper as a result of administrative processes. This is valuable waste, but it comes with a risk: the confidential information it might contain and the need to destroy it as per the GDPR.

Glass

Characteristics:
- This waste is 100% recyclable. It is very heavy and does not degrade or burn, so it either takes up its volume in the field for eternity (like other inert materials), or it is recycled and used as a raw material in glass factories.
- It is a conglomerate of materials with a **density of 150 to 250 kg/m^3** (in a container).
- When the container is dumped into the truck, the glass breaks, which has a positive result: more weight is transported in the same space. However, it generates a lot of noise, so the **collection schedules have to be adjusted so as not to disturb the public during times of rest.**
- There is another option for managing glass waste that relies on a closed system in which the user returns the empty container to a specific point. This system makes it possible to re-use certain containers without having to melt them, but it poses significant challenges, such as the reverse logistics or quality control of the waste.
- Like paper, glass is a type of waste that does not give off any odors, so pick-up can be delayed until the container is full. I**t is also preferable to increase the number of containers, thus reducing the collection frequency and optimizing the cost.**

How it is generated:
- **Household production** ranges from 5 to 10 kg per inhabitant and year in Spain.
- **Hospitality**: very high production. This type of waste is also difficult to store, so it is advisable to provide the owner with the means to deposit it correctly. Using storage containers with wheels is a good alternative to facilitate transport to containers on public roads.

Organic

Characteristics:
- Organic matter, which is the most prevalent type of household waste, has an advantage when it comes to processing it, namely it is biodegradable, and we have known for many years how to minimize its impact.
- It is a conglomerate of materials with a **density over 200 kg/m^3** (in a container).
- It is a residue that ferments and give of a smell that makes important having a high frequency of collection.

- It's simple, and it only takes a few months for its organic chains to degrade to gas: methane (we can use its energy) and however much CO2 it took in over its lifetime.

How it is generated:

- **Household production** ranges from 50 to 100 kg per inhabitant and year in Spain.

Light Packaging

Characteristics:

- They can be collected together because they are later separated in a sorting plant.
- It is a conglomerate of plastic, metallic and cardboard materials for drinks and **other uses**, with a **density of 20 to 30 kg/m^3**. (In container) (very light).

We expect to collect between 5 and 20 kg per inhabitant per year, with different amounts depending on the system used to distribute containers.

- This container, because the public is asked to recycle several materials and because its purpose is "to recycle", **can mistakenly lead people to think that all recyclable waste must be deposited in it.** But this is not the case. On the one hand, because of how packaging sorting plants work. Not everything that people think is recyclable can be recycled, for example, a handbag.

And on the other, for reasons of economic efficiency. Why send paper to a plant, where some employee has to sort it from the remaining waste (cost), when it can be put it in its proper container and sent directly to recycling (cheaper = more efficient)?

- To avoid this problem, containers have to be designed with small openings that discourage depositing waste other than packaging.
- This waste type does not give off any odors, so its pick-up can be delayed until the container is full.

How it is generated:

- Voluntarily by individuals, from 3 to 15 kgs per inhabitant per year.

- From the hospitality sector: very high production, it is also a waste type that occupies a lot of volume, great potential to improve its processing.

Light Packaging

A simple glance at our garbage shows just how many empty containers are in it. Cans of preserves or drinks, water or soda bottles, milk or juice cartons and single-use plastic bags that are only useful for a short period of time.

This item is relatively new in our trash and it is showing up more and more. **The point is not to stigmatize light packaging.** We need it to enjoy the quality of life that we have come to expect. It is convenient to open the refrigerator and find cheese, milk, eggs, meats, and more. **This**

packaging makes all that possible and it is an essential element in the process. The point is using it in a way that doesn't harm our environment. And that requires recycling.

Which materials are included?

- **Plastics:**
  - HDPE and LDPE (High- and low-density polyethylene).
  - PET (Polyethylene terephthalate)
  - PVC, in decreasing amounts.
  - Polypropylene.
  - Polystyrene
- **Metals:**
  - Steel
  - Aluminum
- **Cardboard or Brik packaging for food and beverages.**
- **Wood and others.**

Light Packaging - Specifities

These materials are recycled or reintroduced into the consumption chain separately: polyethylene is extracted from polyethylene and PET from PET, **but nothing useful is obtained from a mixture of the two.**

The fact that many materials are involved complicates the separate collection option, because **it would require having at least 7 different containers** and sorting the plastic at home in at least 7 bags, plus bags for paper, glass and all other trash.

- Would it be beneficial then to separate each of these flows separately?

- Obviously, there is no home or family that will do this if it can be avoided.

As long as sorting by the public remains optional, it's not easy to argue that complicating things will streamline the problem.

To maximize recycling, an intermediate step has been implemented between the end consumer or recipient of the material, the company that manufactures pellets or flakes for plastics and the producer of the waste, citizen or consumer: **the sorting plant**.

A sorting plant is a facility where materials collected together are separated into fractions before being sent on for recycling.

Setting up these facilities makes it possible to rely on the public's collaboration by **reducing the number of bags at home and containers on the street**. We will see in more detail how these facilities work in the last section of the module.

Light Packaging - What has to be deposited?

This fraction should contain **all packaging except any made from cardboard,** which should go into the paper container, **and glass,** which also has its corresponding container.

The result is sorted materials that are free or partially free of other impurities or materials that cannot be sorted or recycled, in sufficient quantities for sorting and delivery to recyclers. This system, in which specific containers are made available to deposit these materials, which are then collected and transported to a sorting plant, **is not financed through the sale of the recovered materials**; therefore, in application of an environmental protection principle, **its financing has been passed on to the consumer through Integrated Management Systems**.
Next tasks will be related with Integrated Management Systems.

1.2.2 Waste collection
A logistical Challenge

Introduction

We have seen the most common municipal solid waste, its characteristics and related factors.
If everything I collect is going to end up in a landfill or in an energy recovery facility, **that is, if I am simply going to bury it or burn it, or there is no market for the recovered materials, then it makes no sense to separate it**, meaning I won't bother with separate collections.
Unless I'm required by law to protect the public environment.
Either because I have a market and am interested in recovery, or because a law is in place that requires me, as an administration, to implement selective collection systems, **I must choose which dumpster system to install. Location and number.**

Kinds of waste collection strategies

If, as is the case in Europe, I focus on the recovery of the light packaging fraction, I will have:

Close to residents	Grouped
	DROP-OFF AREAS
 Miscellaneous waste	 Packaging + glass + carboard/paper
OR PROXIMITY COLLECTION	

 Packaging + Miscellaneous Fractions	 Glass + Carboard/paper

Who decides which system to implement?

National waste strategies that convey recovery and recycling strategies. **Compliance with these directives/laws or strategies steers the implementation toward one system or the other.** If **I set packaging recovery targets**, **I will focus the collection system on one of the above alternatives.**
How is it financed? In the European case, **local administrations finance separate collections through integrated management systems** that in turn promote one of the systems focused on the packaging fraction in order to achieve recycling targets.

When the recycling targets for certain types of packaging increase, **complementary strategies are set up to increase their intake**. These may include the establishment of new collection systems or the use of new technologies implemented in the current set of dumpsters.

There are examples, such as the RECICLOS project in Spain, which in order to meet the collection targets for beverage cans and plastic beverage bottles, reward the commitment of citizens. This project has a dual aspect, one with new collection elements, such as RECICLOS machines (RVM), and another focused on the use of the smartphone and the current dumpsters.
Find more information at www.reciclos.com
But when we are faced with making the decision, **there are several factors that we have to take into account:**
The ultimate goal of separate collection (that is, why we bother residents by asking them to have several bags in their homes) **is to achieve the lowest impact with the maximum recovery rate.** Therefore, **it is the available technologies that will determine the best option** in terms of waste processing.

Materials from the separate collection of packaging sorted at home yield higher recovery rates than if they had not been sorted. The less material that passes through the sorting belt and the purer it is, the more that will be recovered, just as in a mining facility.
In any case, it is a political decision. The more fractions we separate, the more expensive it is to collect them, naturally.

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Choosing the system. A problem of territory and cost.

Once a system is chosen, the solution has to address the following criteria:

- **Facilitate my clients' access to the service**. (Door to door or at stops or drop-off points, just like the distribution of goods)
- **Establish a collection system that minimizes costs**.
- **Satisfy transport quality criteria**. In other words, choosing between having one bus that comes immediately for every two citizens, or waiting for one every two hours so it is full and costs less. It is a function of **balancing service and cost**, a common and widespread problem in public activity.

Limiting factors

A garbage collection system is the same as a mail delivery or beverage supply system, or any other system.

First of all, **I must provide the service to all users**, always based on value for money. (The important thing is the service).

I will try to buy trucks large enough to carry as much waste as possible, within the limitations imposed by my transportation system (vehicle size, schedules, etc.). Compaction whenever possible.

My **limitations involve load capacity** (vehicle) **and time** (operator). Both **limit utilization and define my needs**.

Returning to the bus example, if the cost of the driver is the same whether transporting 10 people or 50, why are there no buses with 250 seats?

The various traffic regulations limit the maximum size of vehicles that can drive on the road. This, together with the small streets in certain neighborhoods and old city quarters, limits the size of the collection vehicles.

How is a truck outfitted for waste collection?

These vehicles are **specifically designed** to collect and transport solid waste. In general, they have a **compaction system to optimize the weight transported**, since the truck's capacity in terms of mass is greater than that occupied by uncompacted waste.

It has a reinforced closed box to keep it from bending under the force of the compacted load, hence those vertical crossbeams it usually has.

The load capacity depends on the box that we place on the body. It is interesting to note that the cost of the compaction system is basically the same whether the box is 15 or 18 m^3. **If the chassis is also the same, the only difference in cost in installing a 15 or 18 m^3 box will be just a few centimeters of sheet metal**, since the expensive part is common to both trucks. **It is thus prudent when sizing the box to make it as large as possible for the chassis size.**

In this video you can find an example of how a recycling truck is made:
https://youtu.be/dRAnI4FnwPI

Collection criteria II

Returning to the criteria that we set:
How can we make it easy for my clients to use the service while minimizing costs and ensuring the quality of the system?
If we continue with the bus service analogy:
Ideally, a bus would pick you up where you are and take you wherever you want, but that is a taxi, not a bus. A "taxi" would not be economically viable for collecting waste.

The second option is a regular line. A bus makes the **same round trip** and stops on its way to pick up everyone who **requests it and lets them out**, within the route, wherever they want.
As a service, it works. The only drawback is that someone **going to the end of the line** won't know when they will arrive, since it depends on how many people **get on and off** along the way. The service is good for some and bad **for others**.
We tend to be in a hurry and we want to know - more or less - when we will get somewhere, which is why the **bus stop system** has been developed. **Pick-up points** for people**.**
In other words, someone who has thought about this problem gives us **the solution. "PICK-UP POINTS".**

Collection criteria III

The same happens with waste: a series of collection points has been developed where we, the residents, know that we can deposit our waste and that it will be collected every so often, thus avoiding the inconvenience it creates.
Why have we opted for this type of model?
- **It allows for drop-offs at any time (production is continuous in time).**
- **By being closed, it avoids any visual impact.**
- **It facilitates fast loading using mechanical means**

Now that we have seen the benefits of a collection point system using dumpsters, a fundamental decision remains to be made: **The type of dumpster.**

For most waste fractions, the answer is "as big as possible", especially for fractions such as light packaging, which do not create odor problems. **But, why prioritize the size?**

Mainly because, **as we saw in the limiting factors, my operational limitations involve load capacity** (m3 of truck when it is full is not of much use until I empty it) **and time** (operators' work day).
From this point of view, it is preferable to have a 3,200-l dumpster instead of four 800-l dumpsters because I will collect the same waste in a quarter of the time.
However, when the collection is very limited, it is cheaper to half fill an 800-l dumpster than to have a nearly empty 3200-l dumpsters.

Sizing the system

Introduction

When selecting which dumpsters to install, there are other factors besides size to consider. **I have to analyze**:

- What kind of solid do I want to transport? Purulent, large, small, what shape, cylindrical, spherical, length, height, etc.
- How does it get to me? In boxes, in bulk, in large sacks or in bags.
- How much is there? One box or 200, one ton or 1,000 tons
- Where from? From a pile in a warehouse… from several warehouses.
- And what is on the market to solve it, types of trucks, bags, loading systems, etc.

I have to set a level of safety or service, that is, I can't tell my client that I am not bringing him another kilo of merchandise because it won't fit.
As a result, I have to:

1. Know the type of waste.
2. Identify my "clients". (**ZONING**)
3. Identify production. (**AMOUNT**)
4. Know the environment, (**TECHNICAL CRITERION**) difficult to quantify with objective parameters.
5. Have safety margins (**OVERSIZING**)
6. Service criteria. (**DISTANCE**).

1. Know the type of waste

We have already seen the first point. **What the solid waste is like grouped** (miscellaneous fraction or Municipal Solid Waste fraction) **and separated.**
We have seen its density and the expected amount, that is, we know the general extent of the problem.

The distribution of these dumpsters on the ground has to take into account the **non-homogeneous population distribution.**

Cities have areas with large buildings alongside businesses, upscale single-family homes and substandard housing, leisure areas and parks with and areas for administrative use.

In other words, dumpsters have to be located where they are needed, that is, where the waste is produced.

But it is not just technical factors that determine the size of the service; there is a fundamental factor, namely **COMMON SENSE**.

Let me explain:

I'm not going to put dumpsters at the door of the cathedral, or in the narrow streets of the old part of town where trucks don't fit, or just outside a police station, lest someone think to put a bomb in it.

When you are responsible for the service, you can't do certain things on the ground that you can do on paper.

2. Identifying my cients – Zoning

To say that the inhabitants of a city are all equal in terms of waste production and contribution is a more or less valid simplification as a whole, but it won't yield the most practical solutions, and the system will have to undergo a series of adjustments over time.

The challenge is to **identify or size the number of dumpsters needed where the waste is produced**, that is, to put more where I need it most and as close as possible to the amount I need. If I can do this, I will save taxpayer money.

For example, Madrid has 3.2 million inhabitants organized into 21 administrative districts, which are in turn divided into neighborhoods.

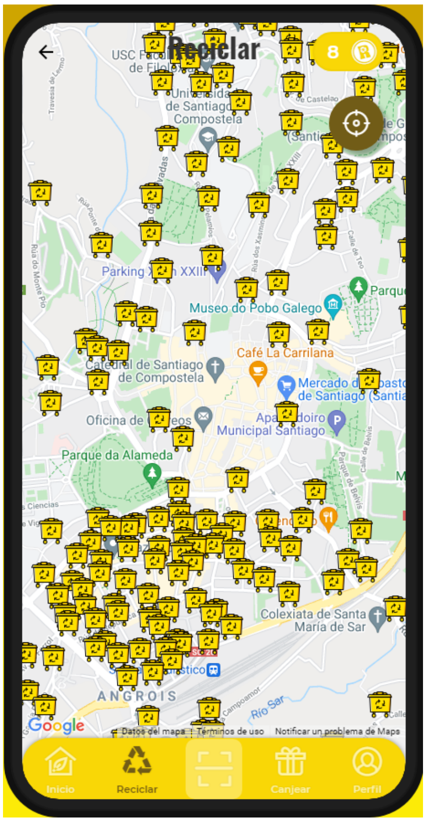
The closer I zoom in, the better I will see the problem.

In this case, the central district with its tourist and commercial traffic and old and narrow streets is not the same as the outer districts, which have more housing and less commercial and administrative activity.

If I can analyze the needs of each district, or even each neighborhood, separately, and **if I also know or can at least guess or sense how this urban distribution affects waste production**, **my system will be more appropriately sized than if I only look at the big picture.**

This explains the need to analyze, if required by the size, the population distribution and to allocate waste production by more or less uniform, identifiable and distinguishable zones.

Next picture is part of RECICLOS project, as you can see the distribution of the yellow containers in Santiago de Compostela is different depending on the characteristics of each neighborhood.



3. Identifying production – Weighting

Once we realize that there are different types of areas in terms of how waste is generated in a municipality, we then have to try to refine as much as possible the percentage that each area contributes to that waste generation.

First, we have to determine if the **production of that area's population is above or below the average**. To do this, we have to look at factors such as the economic level or its commercial use:

The waste in commercial areas is expected to come from registered businesses and those who go there to enjoy the sights, the cuisine or who work or study there. It is thus reasonable to think that the number of people entering this area daily exceeds the number of its residents who leave for other parts of the city to work, **meaning it will have more garbage.**

There is no good or bad data, the weighting depends on the experience and Common Sense of the planner who applies it. It's logical to think places used mostly to sleep generate little trash. It's also logical to think that commercial establishments throw away a large amount of packaging. So garbage is produced both by residents and visitors, with the latter being lower in density.

But we **can't assume** that allocating the dumpsters in this way will result in them **being filled at the same speed or uniformly**, meaning **a higher installed volume is needed to handle peak traffic.**

4. Technical criterio

It seems reasonable to **size the volume needed** to solve the problem **not by considering an average day, but the days with the highest production**.
I have to add a safety margin to my calculations that allows me to handle surges in production due to increased consumption, peak days, etc. Because not every dumpster will be full when I go pick it up. Some will be fuller than others, even if they are in the same area, for objective reasons that are unknown when the system is sized.
It is essential, therefore, **to conduct a proper analysis and study of the data that takes into account previous experience.**
For example, I am more likely to use a dumpster if it is on the route I use to take the kids to school, if it is close to where I parked the car, if it is downhill, etc.
I could have two dumpsters that provide sufficient volume, but one full or overflowing and the other one half empty. It is because of these unexpected or unquantifiable reasons that they contain different amounts of trash.
To alleviate these points, I must make available a larger volume than is strictly necessary.

5. Oversizing

The safety margin can also be determined by objective reasons on the ground. **I will place more dumpsters where they have a greater impact on the city if they overflow.**
An overflowing dumpster downtown is not the same as in the suburbs. That may not seem right, but that's how it is.

There is another safety margin involving the distance between residents and the dumpster. If the population density is low, I will need more dumpsters so they are relatively close to the residents. This is determined by the population density: **a small population in a large territory will force me to install more dumpsters than are strictly necessary.**

This allocation is theoretical, based on technical criteria that are difficult to define and quantify. **A good planner is one who has a "good nose" for analyzing these conditions.** The dumpster system I propose will not be perfect, and it will need adjustments, but these will be minor. **The important thing is to implement indicators, metrics and adjustment systems so I can refine it.**
Later, we will se an interview about how new technologies can help us to implement better metrics and data analysis for waste management.

6. Service criterion - Distance

Is walking 3 minutes roundtrip from my door to the dumpster a lot?
Well, it will depend. For many people it is, and for many others it isn't.
-If the alternative is having my street full of trash...
- And if they can also fine me for leaving it on the street...

In any case, **it is a matter of economic balance**. For clusters of people living close to each other, large buildings with more than 5 floors, it will be closer, and for isolated areas, I may have to go as far as 150 m. **There is no single formula for every case.**
In other words, the maximum distance from a dumpster to a resident is less than 75 meters in urban environments and around 150 meters in more open or rural settings.

Transporting waste

Available collection technologies

Especially-adapted trucks are used to collect waste when using a system of pick-up points.
These collection trucks usually combine **two key technologies** to streamline the waste management model:
- Loading technologies (seeking to minimize the time required)
- Compacting technologies (seeking to maximize the load)

However, they have to **deal with a number of physical and legal limitations**:
- The physical ones have to do with the **space needed to collect trash in urban settings.**
- The legal ones involve complying with the r**equirements of the traffic laws, since this work will be carried out on public roads.**

Where can one buy these trucks? Can I buy one for myself to go camping?
Truck manufacturers only sell the chassis. It is the **TRUCK BODY BUILDERS who put things on top of them**. Which one I use will depend on what I want.
In Spain, one company installs cargo boxes, ROS ROCA / (Normally, in France (SEMAT) or (SITA), in Italy (FARID, OMB), in Holland (GEESING), in SWEDEN (NORBA)), we deliver the truck after confirming that the box they sell can be installed on the truck, and they install everything that is needed. **The truck then gets approved by the government and it can be used to collect garbage.**
The government approves them for use by way of the **technical inspection that these vehicles must undergo every year. An engineering project is also required that must be endorsed or approved**, and which basically specifies the weight distribution per axle, full and empty, such that its range is between accepted values based on the characteristics of the chassis, brakes, etc.

Truck technologies

We have already seen the first point. Main characteristics about collection trucks, but before detailing each main model, we will describe two common technologies. We will use the simplest loading system for it, the one composed by a chassis + a box.

Loading capacity:

This example is composed by a truck outfitted with a box as large as the dimensions of the truck allows, into which the garbage can be deposited.

Used to pick up furniture and other items (from 6 to 8 tons), **boxes of 12 to** 14 m3

This system has one problem: as we have often seen, **trash has a low density, and this wastes part of the truck's weight-carrying capacity.**

How do we solve this? We can look at Japan, which has always been a leader in terms of cutting-edge technology.

Compacting is a technique that will allow us to reduce the amount of empty space.

Compacting in truks:

Technologies have been developed that "**compress**" the waste by using hydraulic cylinders so it takes up less volume, thus optimizing the carrying capacity of the trucks and reducing the collection costs.

The compaction ratio by volume achieved is 5 to 1. A ratio of 5 to 1 means that 5 m^3 in a dumpster can be compressed to just 1 in the truck box, going from 120 kg/m^3 to 600 kg/m^3 in a truck.

If the maximum load capacity is 12,500 kg and the largest box is 25m^3, this yields 12,500/25 = 500 kg/m^3

Types of truck loading systems

Next pages will focus on different types of truck loading systems. There will be 5 main groups and the last two will be composed by the less common but not less interesting systems.

Main types of truck loading systems:

- Through the top. With a crane. **Top-loading**
- On the side. **Side-loading**.
- Through the rear. **Rear-loading**.
- Other, less common types
- **Pneumatic collection**

Rear-loading systems

Characteristics:

- **The operators bring the dumpster to the truck**, place it under the elevator and actuate the lifting and unloading system.
- Despite the safety measures, **the proximity of the workers to the lifting mechanisms can be dangerous.**
- Among other things, it is recommended for **places where only one truck is needed.**

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- The **best thing** about this system is that **it is the operators who load the waste** by bringing the dumpster closer. **If there is any waste outside, they put it inside.** If someone has left a mattress box spring or a baby carriage, they can put it in. Automatic systems do not allow for this option.

Key aspects	
Versatility. I can load anything, since the process is manual.	Regulations for transport operators will hurt the collection time. If the operator has to get in the cabin between stops
Easy replacement, it is a very common system.	High labor cost. 3 operators per truck.

Side-loading systems

Characteristics

The collector is equipped with two video cameras, one on the top (focused on the dumpster at the tilt point) and one on the side, looking at the side of the collection vehicle. **In the driver's cabin there is a computer control system and a monitor.**

In this video you can see how it works (with an epic soundtrack...):

https://youtu.be/zbdQDFLwL9U

Source: Econovo channel in youtube

It has a higher investment cost than a rear-loading truck, and would only be feasible when collecting a lot of garbage. As in the previous case, the technology is the same regardless of the size of the box, and **it is an expensive technology** (television cameras, sensors, etc.), **meaning the largest box possible is installed.**

I won't put side-loading systems for populations of less than 20,000 inhabitants, more or less what can be collected with a single truck. Why?

The minimum side-loading system is two trucks, which is for about 40,000 inhabitants, because if one of them breaks down, the other one can be used on a different shift, i.e., on two daily shifts, while the first one is repaired. **If I only have one and it breaks down, there is no back-up system other than another side-loading truck**.

Given the small size of the municipality, there may not be any other side loaders in nearby areas that can help me out.

Problem

The waste has to be inside the dumpster.

What if there is garbage outside?

We need "clean-up" crews. An operator with a vehicle drives along the collection routes in front of the trucks, removing the trash left outside, or leaning against the dumpster.

Key aspects	
Automatic loading. No manual handling.	Dumpsters located to the right of the truck.
Needs CLEAN-UP crew.	High investment, but offset by lower labor costs.

Top-loading systems

Characteristics
Top-loading truck

- The operators hook the crane to the dumpster, raise it over the box and open the lower lid with a winch so **the garbage falls due to gravity.**
- This system is **intended for large volumes and weights**. That is, waste that can be collected.
- **The winch is a double hook system**, one keeps the dumpster upright, and the other one is lifted to open the base of the dumpster and empty it.
- The design criterion is: The box is as big as possible. And what crane do I use?
- The criteria when ordering a crane from a manufacturer are **how many kilos I want to lift and how far.**

Key aspects	
For loads that allow stockpiling or storage	No compaction. (glass) paper? Packaging with compacting.
Longer cycle time than other systems due to its loading system, that is, fewer dumpsters per hour.	With or without remote crane operating systems

Other less common types

Front Loading:
Not widely used, provides no comparative advantages versus a side-loading model and **hampers access to the dumpster, since it has to be approached from the front.**
Two-compartment boxes:
Used in order to collect two types of waste at the same time.
In a large city, they only make sense to avoid having two trucks driving on the same route to collect different waste types.

It makes the most sense if neither box is filled and it covers long distances. If I pick up 10 m^3 of MSW and 8 of packaging and I have two trucks, I spend twice as much on fuel and operators than if I use this solution.
Neither box is filled 100%, I have to unload when one of the two boxes is full.
Two comparment boxes trucks.

Primary-satellite system:
Most European cities have old centers of medieval origin, narrow streets, where people live (the historic center.)
Because of the narrow streets, balconies, etc., only small trucks are maneuverable enough to fit.
The waste treatment plant or landfill is, let's say, some 20 km away, it takes about 20 minutes to fill a truck and 45 to make the round trip to the plant. What do I do?
Combine small (satellite) trucks to collect the trash in narrow areas with large (primary) trucks that receive the waste from small ones for transport.
Primary-satellite system

Pneumatic collection

Characteristics:
There are methods that do not require collection trucks and that work with a network of underground pipes that work using suction.
Each drop box has a valve that allows the trash to be suctioned either when the container is full or on a set schedule.
A "suction" plant regulates the system.
At the plant, the trash is compacted in a **static container and transported by truck** to the processing plant.
This is a significant investment. Payback period of 30 to 50 years.
See how it works in the next video:
https://youtu.be/qEkiAugc1GA

1.2.3 Sorting Plants Introduction

In this lesson we will study:
- Key aspects
- Materials
- Processes

that a sorting plant includes. We will work with the Spanish model, one of the most common in Europe, but later we will see the other widespread alternatives.

Sorting plants models in Spain

To better understand the sorting plants, this first chapter explains in detail one of the standards for the sorting plans (the one established in Spain for the 95 facilities receiving domestic light packaging financed by Ecoembes). In addition, the chapter explains the differences with other standards. **Spanish sorting-plants model**

Waste treated in light weight packaging sorting plants in Spain is obtained from the selective collection of yellow dumpsters, where citizens deposit domestic light packages. These are plastic, metal and food and drink carton packages and beverage carton. The containers contain impurities or unsolicited material which must be separated from the requested materials during the sorting process.

Requested Materials

Requested Materials:

HDPE (high density polyethylene)

PET (polyethylene terephthalate)

LDPE (low density polyethylene, generally in film form)

Mixed plastic fraction composed of materials made of PS (polystyrene), PP (polypropylene) and other plastics;

Also included:

Aluminium

Steel packages

Beverage cartons (hereinafter BC).

Unsolicited materials:

Cardboard

celluloses

P/C

low and high-density film plastics and

other impurities such as glass

textile wood

non-packaging plastic

organic matter

other metals, etc.

Treatment process in a lightweight packaging sorting plant

Groups of operations:

The treatment process in a lightweight packaging sorting plant is divided into four main groups of operations:

- Reception and storage.
- Pre-treatment.
- Sorting of materials.
- Quality controls, adaptation of selected materials and rejected waste management.

These operations will vary depending on the automation level of the sorting plants. Facilities are classified **as automated or manual** depending on how the material sorting operation is performed.

Sorting plants Diagrams

In this page you can see two diagrams: **one for the automated sorting process and the second for the manual one.**

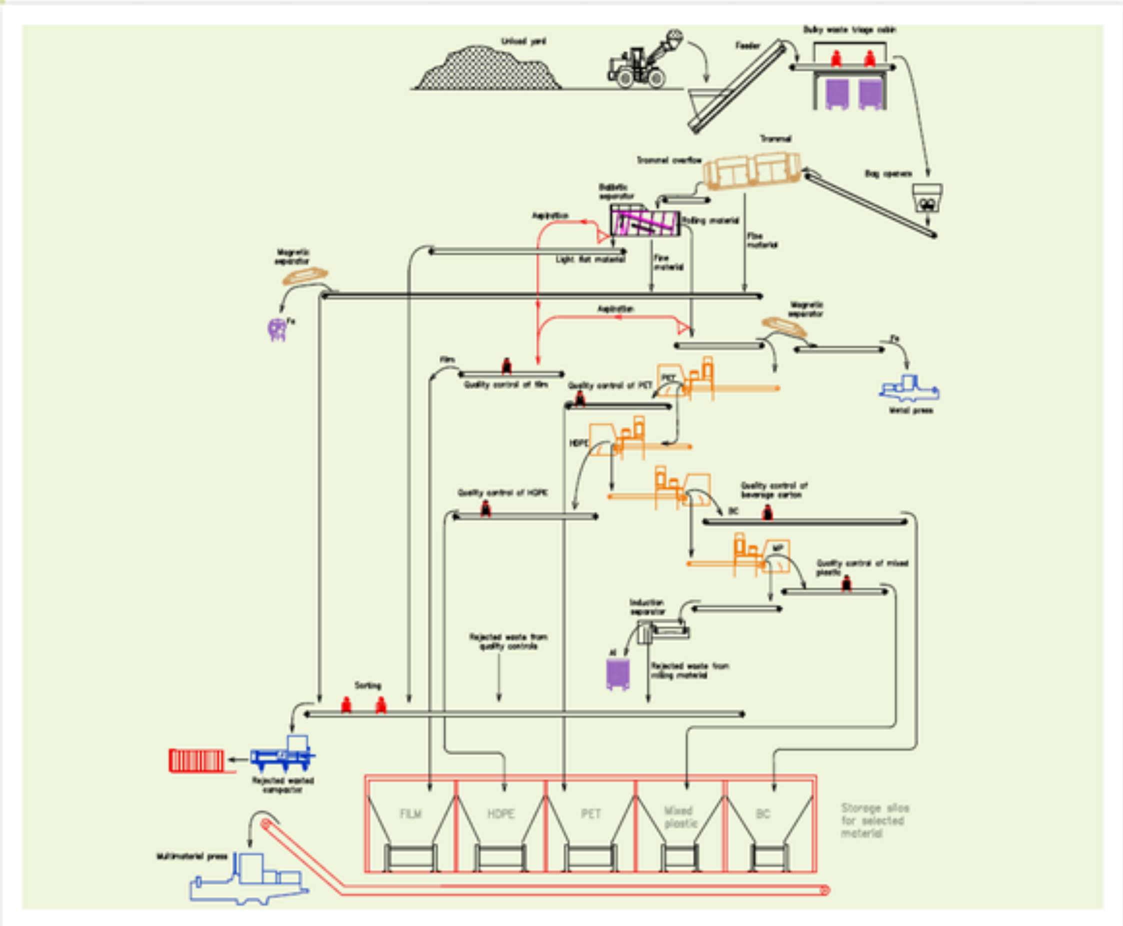

Figure 3. Diagram of the automated sorting process. Source: Elaborated by ECOEMBES

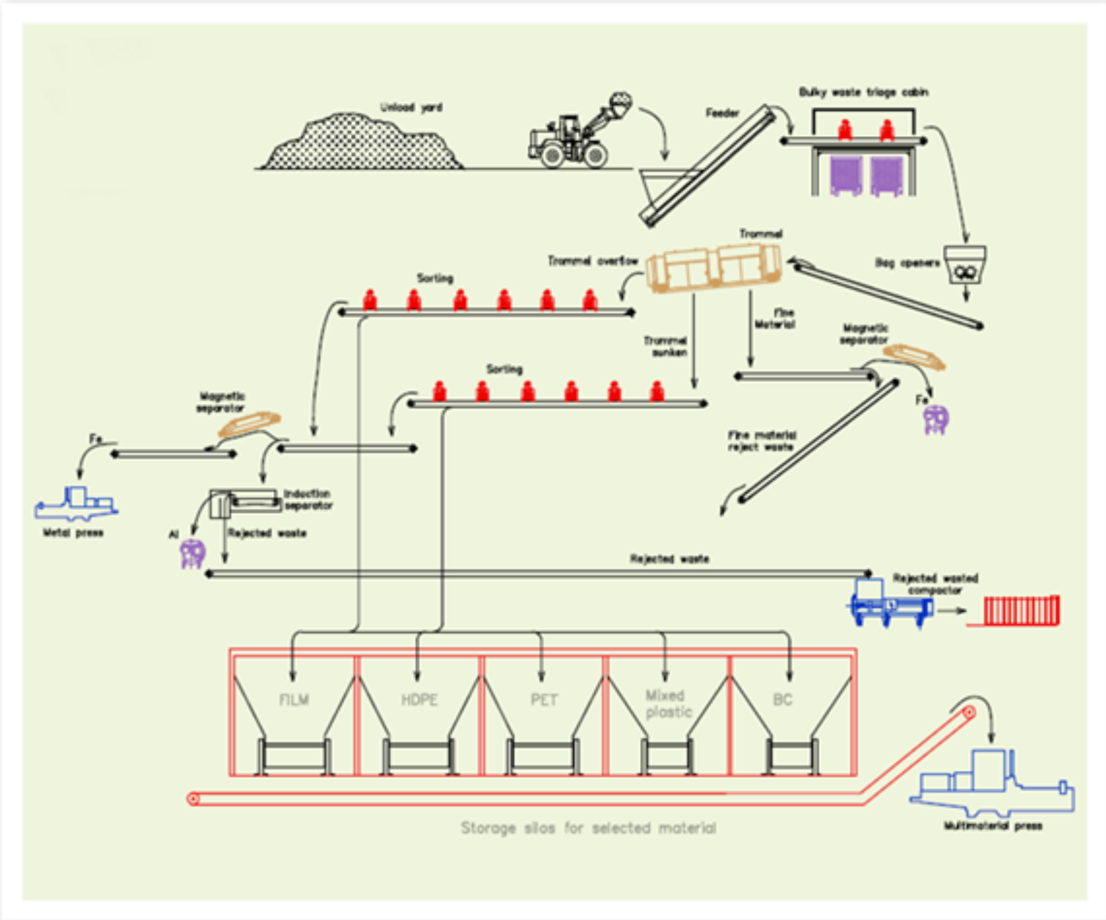

Figure 4. Diagram of the manual sorting process. Source: Elaborated by ECOEMBES

Reception and sorting of materials operations

Introduction

In this lesson we will go more in depth into the two first groups of operations:

- Reception and storage operations
- Sorting of materials operations

This lesson will cover the process between lightweight packaging arrives to the sorting plant until it is divided into the different material flows.

Reception and storage operations

Scales for monitoring and weighing of collection vehicles:

Vehicles with packaging waste collected from streets arrive at the sorting facility passing through **access control and weighing (scales)**.
In order to transport the collected material more efficiently, **when the street collection vehicles need to travel great distances** from the place of collection to the destination plant, it is convenient to unload the material at intermediate locations (**transfer stations**) for compacting and subsequent transport in larger containers, if possible and those facilities exist.
In this case, the material arriving at the plant has a bigger density, which must be considered when sizing the treatment capacity of the facility.

Reception and storage operations II

Unloading area for transported waste:
After weighing the vehicles and identifying their origin and schedule, they are led to the covered reception area where the transported waste is unloaded in the area or location indicated by the discharge and feeding operator.
Positioning and stacking of unloaded waste:
The loading shovel stacks the unloaded waste vertically, optimising the surface available for storage prior to treatment. **This process can include several components of bulky waste with sizes or shapes** (as in mattresses, large packages, bicycles, etc.) that hinder the work and could affect the sorting equipment to be used. **Using the loading shovel the operator must place these in a specific container located on this or another surface.**

Reception and storage operations III

Pre-treatment operations:
Pre-treatment operations are those performed once the material has been stored and before its separation into the different material flows
Primary feeding-dosing:
The waste deposited in the reception area is collected with the loading shovel (unload yard) or grapple hook (pit), transferred and unloaded in the dosing feeder with variable speed and flow limiter, used to control the treatment flow rate.

Bulky waste sorting:
Waste regularly recycling supplied by the feeder is unloaded in a bulky waste sorting conveyor belt, where sorting operators select the materials which due to their size or shape are detrimental to subsequent treatments, such as film sheets, cardboard, EED waste, etc. **The selected bulky materials (recoverable and non-recoverable) are stored in containers located under the sorting cabin for delivery to the recycler or the treatment rejects section.**

Reception and storage operations IV

Bag opener:
Non-sorted waste is downloaded by the same sorting belt in a bag opening unit designed to extract the materials from the bags when they are ready for the remaining sorting operations.
Classification in trommel:
In many cases, the components of the bags are subjected to a sieving process using a trommel or revolving sieve, which classifies the materials into three sizes:
• Fine components with a high content in organic and inert material.
• Intermediate components with a high content in recyclable packages.
• Large components or sieving rejects.

Reception and storage operations V

Classification in ballistic separator:
The stream of intermediate size materials of the trommel, if that exist, or from the bag opener directly, if that doesn't exist, is subsequently subjected to ballistic classification according to size, shape and density, and again separated into three new material streams:

- **Stream of heavy-rolling material** formed by the majority of the heavy and/or rolling material, mainly packaging for liquids, metal packaging and beverage carton. This falls down the inclined slope of the ballistic separator.
- **Stream of light flat materials**, mainly formed by cardboard, paper and other film plastics with a flat or flattened shape that rise up the inclined plane of the separator.
- **Stream of fine materials** made up of fine material that could not be sieved in the trommel because it was attached to or blocked by other material, which falls through the mesh of the separator.

The amount of material reaching each of the three fractions will depend on the quality of the material introduced in the equipment. For examples, in facilities with 75-85% of requested material at the inlet, the classification performed by a ballistic separator is about 80% rolling material, 15% light flat material, and 5% fine material.
At facilities where the sorting operations are performed manually, the ballistic separator is not used. The material arriving from the trommel, if exists, is taken directly to the sorting cabin, where the operators sort the requested materials

Sorting of materials operations

Pneumatic separation:
The main objective of pneumatic separation is to clean film and paper from the rolling and light flat material streams, since these hinder the segregation of the remaining materials.

The selected material is subjected to a manual quality control to separate impurities. It is subsequently stored to prepare it for dispatch (compaction).

Magnetic separation:
The rolling material stream obtained from ballistic segregation is subjected to segregation of magnetic materials (steel) using over-band separators.
Similarly, the fine material fraction from the trommel, if the plant is equipped with this equipment, and ballistic separator are subjected to magnetic material sorting before being sent to the rejected waste fraction.

Sorting of materials operations II

Optical separation:
The rolling material stream that has not been selected by pneumatic aspiration on this line nor by the magnetic separator is subjected to optical segregation by infra-red or colorimetry detectors to segregate the following requested materials:
- PET packaging
- HDPE packaging
- Beverage carton packaging
- Mixed plastic packaging.

To improve the performance and quality in the sorting of these materials, the magnetic and pneumatic sorting must take place prior to the optical separation.

Induction separation:
The stream of materials not sorted by the optical separation is subjected to a sorting of non-magnetic metals (aluminium) by an eddy current separator.

Manual separation:
Materials not selected in the rolling and light flat material streams converge on a belt in which they are subjected to manual sorting. The remaining unselected material is sent to the rejected waste fraction.

Quality control, material adaptation and rejected waste operations

Introduction

In this lesson we will go more in depth into the next three groups of operations:
- Quality control

- Material adaptation
- Rejected waste management

Quality control

Quality control:
Due to errors occurring in the different types of equipment, the selected packaging material contain impurities that reduce the purity of the final product.
These impurities are removed through manual sorting. This operation is usually performed after the sorting of each of the recovered materials (PET, HDPE, beverage cartons and mixed plastics) before storing in silos for compaction.
In other facilities, the quality control is performed before compaction, so that a single operator can perform the operation.
The sorted impurities are sent to the rejected waste stream at the facility or, if they are requested materials, recirculated to previous points of the process for sorting.

Material adaptation

Temporary storage of selected materials:
The selected materials are deposited in specific confined spaces for each one (intermediate storage silos) awaiting compaction operations. Storage silos are compartments sized according to the following parameters:

- Apparent density of each material
- Production of each selected material per shift
- Hourly capacity of the compacting press.

The extraction of the materials stored in the silos is performed using moving bases, conveyor belts or directly with a loading shovel, which evacuate them to the feeder of the baling press placed downstream.
If the selected amount of any material is small (e.g. aluminium) the production is stored in auxiliary containers for subsequent compaction.

Compaction of selected materials:
Materials stored temporarily in the containers are subsequently subjected to density increasing operations using baling presses, which produce bales with a density suitable for final storage and subsequent transport.

A single properly sized press can bale the output of all selected materials (PET, HDPE, FILM, beverage cartons and mixed plastics) except metals, and particularly steel, which require different bale sizes and features as well as specific presses.

Rejected waste management

Rejected waste management at the facility:
All sorting facility rejects are typically concentrated on a single output conveyor belt that discharges them at the evacuation point. Occasionally the fine materials current is discharged at different points from other rejected waste.
Due to the low density of the rejected waste material, its volume needs to be adapted for an efficient disposal to the landfill. This can involve several alternative systems:

- Self-compacters.
- Static compacters.
- Rejected waste press.
- Containers (for low-volume facilities).

Transport of containers with rejects is performed using container vehicles to take them to processing sites (landfill or energy recovery).

Differences among plants
The model presented is a standard designed in Spain to define the sorting plants for light packaging.
Not all these plants follow the standard literally; there are differences among them. The operations in a sorting plant will vary depending on the automation level of the sorting plant. Find here some differences:

- There are facilities with discharge pit and facilities with **unloading yard as a reception area.**
- Treatment lines with **discharge pit are feeded by grapple hook**s.
- Treatment lines with **unloading yard are feeded by loading shovel.**
- There are some **sorting plants with trommel.**
- **Size mesh of the ballistic** separator used to **vary between 50 and 70 mm.**
- Some plants have i**ncorporated optical separation for film**.
- We can find **a lot of different configuration of optical separator chains**.
- I**nduction separation with a different intensity** is used for the sorting of **beverage carton packaging in some plants.**
- The selected materials **quality control is performance by an operator, mostly.** However, we can find optical separator quality control

Different European Models

Introduction

According to the Circular Economy Action Plan the Commission will propose to harmonise separate waste collection systems in all Europe. A**t the future, all the requested materials will**

be harmonised, so a European sorting-plan model should be established. In this subsection some other models in Europe regarding sorting-plants, in which the results could be extrapolated to some extent, are presented.

The typical sorting-plant model in Europe involves several similar sorting steps, as presented in the above Spanish example. These include manual dismantling and sorting by automated processes, separation according to density and size, and optical or magnetic separation.

However, the exact process can vary according to consumer behaviour and collection systems. For example, in the **Nordic countries, consumer behaviour and market availability mean that less beverage carton packaging (TetraPack) is used than in Spain, meaning there is no separate stream for this kind of packaging.**

The collection system used in different countries has also had a large influence on the historical development of MRFs. **When recyclable materials are collected in separate streams, this can reduce the number of sorting steps needed, or free up capacity to sort a greater number of types or grades**. On the other hand, mixed collection of recyclables saves resources at the front end but require a higher degree of technical complexity in MFRs.

Main collection models applicable in Europe

In general, there are four main collection models applicable in Europe (Lorenzo et al, 2016):

Single-stream collection: all dry recyclables (plastic, metal, paper, cardboard, and sometimes glass) are collected together. For instance, this is the main collection model in Greece, Ireland, Malta and Romania.

Dual-stream collection: 'fibres' (paper and cardboard) and 'non-fibre' (i.e. plastic, metal and glass) are collected separately. This is the main collection system in the Finland and the UK.

Mono-stream collection: each material is collected separately (i.e. paper and cardboard, glass, and lightweight packaging), and treated in a MRF. The Spanish model described above fits in this category.

This collection system is the most prevalent in Europe, being applied in Belgium, Bulgaria, Croatia, Cyprus, France, Germany, Hungary, Italy, Latvia, Lithuania, Luxembourg, Poland, Portugal, Slovenia and Sweden.

In addition, some countries further separate the lightweight packaging stream into its constituent parts, including Austria, Denmark and the Netherlands.

Mixed Municipal Solid Waste (MSW) collection scheme: no separate collection of recyclables. This leads to high contamination rates and need for intensive treatment. While the Waste Framework Directive (2008/98/EC) required separate collection of paper, metal, plastic and glass from household waste by 2015, and 50% preparation for re-use and recycling by 2020.

14 Member States were identified as being at risk of missing this target. Ineffective separation of recyclables was cited as a contributing factor in 11 countries (Bulgaria, Croatia, Cyprus, Estonia, Greece, Latvia, Malta, Poland, Portugal, Romania, and Slovakia).

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In practice, however, the collection and sorting model may vary widely within countries, as decision-making powers on the selection and operation of waste collection systems usually sits with local authorities.

Single-stream MRF

The comingling of fibres and lightweight packaging streams requires additional sorting steps to the Spanish example detailed above.

The Ford MRF Plant in the UK is an example of an advanced single-stream MRF. In operation since 2009, it was designed to process 100,000 tonnes per annum of comingled recyclables, **including glass, based on a three-shift operation with 13 manual sorters per shift.**

Conditioning operations: Upon reception, bags containing co-mingled recyclables are opened and fed to the input line. The material is conveyed to a pre-sorting cabin, where items which could damage equipment such as large cardboard, metals, and plastic foils is manually removed. Next, a primary separation process is performed in a two-section drum, in order to pre-concentrate materials and break glass into smaller pieces. Most glass is sorted out in the first section which separates 'fines' (under 75mm).

The second section separates a mixed stream of paper and containers, which is then sent to a double-deck ballistic separator, which separates 3D items (containers) from 2D items (paper). Another stream of fines is also separated at this stage and joined to the fines from primary separation. A stream of trommel overflow or 'oversized' items remains.

Sorting of materials operations: Out of the initial sorting described above, four material streams emerge:

1. **Oversize:** this needs to be cleaned in order to produce its main output - newspaper and magazines - using NIR to remove cardboard and plastics, followed by manual quality control. The output from the NIR is further split by a second NIR into cardboard (which is joined to the 2D stream) and plastic (which is processed using a second ballistic separator to recover any containers for the 3D stream). Any remaining 2D material is classed as sorting residue.
2. **2D stream**: ferrous and non-ferrous components are removed using magnetic and eddy current separation. It passes through a NIR for a final clean before it arrives at manual quality control. Material removed in the NIR is sent to the second ballistic separator to recover any containers.
3. **3D stream**: ferrous and non-ferrous components are removed using magnetic and eddy current separation. It passes through a NIR which removes cardboard and paper (returned to the 2D line), manual quality control, before being flattened and entering the polymer sorting block. NIR sorting divides it into clear PET, coloured PET, natural HDPE and coloured HDPE. The leftover passes a final NIR sorter which removes any missed polymers, which are recirculated to the beginning of the 3D line.

4. **Fines stream:** ferrous and non-ferrous components are removed using magnetic and eddy current separation. It then passes through screening, air density separation and a final NIR sort, resulting in an output of clean glass cullet product (>12mm).

Mono-stream MRF

In Germany, 'Yellow bags' collect a wide range of packaging waste including plastics (including films), cans, and cartons. Glass and paper are collected separately. In addition, large volumes of PET bottles are returned by consumers separately under the German 'pfand' system. Without the challenge of separating fibres from containers, MRFs in countries with separate collection have developed to handle larger volumes of very light waste

Approximately 2.25 million tonnes of packaging are collected each year, 90% of which is sorted in less than 50 plants, with a high level of standardisation in process design (Cipman et al. 2016). **The most advanced plants can have up to 20 NIR sorting machines, plus additional sensing equipment such as ultrasonic or VIS-camera based volume flow measurement devices.**

Conditioning operations: as a first step, yellow bags are coarsely shredded. Materials are then sieved using drum screens (trommels), in order to sort them into workable sizes for the downstream equipment. Plastic films are separated using an air classifier.

Materials smaller than 220 mm are further separated into two or four further particle size intervals. The main mass flow (20-220 millimetres) represents 80-85% of the input stream and is processed on two or three individual lines.

Air classification is used to further separate plastic films (10%), to improve downstream sensor sorting. Next suspension magnets separate ferromagnetic materials (9-13% of the input stream).

NIR sensors are then used to separate beverage cartons, before non-ferrous components are separated using eddy currents (mostly aluminium, <5% input).

Next, two more NIR steps separate paper/ card packaging and all plastics. The mixed plastic is then further cleaned using ballistic separators to remove fines and any remaining 2D material before entering polymer sorting, where plastics are sorted into HDPE, PP, PET and PS.

A second cleaning step or colour sorting (for PET) may also then take place, in addition to a final NIR to detect missed polymers and recirculate them to the beginning of the polymer sorting block.

Complete source separation MRF

In systems where lightweight packaging is separated into its constituent parts at source, specialised sorting facilities are possible. Völkermarkt has been specialised in PET recycling since 2003 and produces food-grade regranulate in its 'bottle-to-bottle' plant (Kruschitz Plastics and Recycling, no date).

PET bottles arrive at the plant in bales, where they are opened and shredded, and passed through a ballistic separator. The PET stream then passes through an NIR separator, and a secondary shredder further reduces flakes to 12mm.

Flakes are pre-washed and sorted using a density sorting/ flotation technique to sort out capsules and other impurities. The PET is then hot washed with sodium hydroxide (NaOH) to remove labels, and waste water from this process is microfiltrated to clean out the glue.

The PET passes through a vacuum reactor to clean it of any organic contaminants, and is finally dried and goes to the extruders, where the PET is melted and pressed through a cone to produce long strings of plastic, which can then be cut into pellets.

As a result, the purity of the resulting secondary PET output can reach 99.9%, with maximum impurities of 100-200 ppm.

Croatian sorting-plant model Mariščina

With the establishment and development of the packaging waste management system, many companies have modernised their existing, or have built new facilities for waste recovery using EPEEF subsidies.

Even though new facilities have been built, and a number of existing ones has been improved, i.e. **the capacities for packaging waste recovery have been increased, especially plastic packaging,** considering that the market for packaging materials is rapidly evolving, an improvement of the existing technology will be necessary, in terms of the technological applicability for the treatment of some types of packaging waste, e.g. for certain types of multilayer (composite) packaging.

Capacities for treatment of packaging containing remains of hazardous matter or being polluted by hazardous matter are, on a national level, insufficient, so it is mostly exported from the RC.

Despite the positive direction in packaging waste management, there exists a need for the improvement of the mechanism of data supervision for the quantity of produced packaging waste, as well as the data on efficiency of recovery (recycling) and the improvement of systems for certain materials (e.g. for packaging except beverage packaging), and the need to establish a packaging waste management system for packaging that contains the remains of hazardous matter or that is polluted by hazardous matter. The existing packaging waste management system does not sufficiently encompass all the types of packaging waste.

Similarities with Spanish sorting-plant model:

Packaging waste in Croatia is collected in yellow containers (or containers with yellow lids) placed in public places and in the recycling yards. Usable material disposed in yellow containers are:

- polyethylene bags, foils, films, bubble wrap – they need to carry the following labels: PE-HD, PE-LD, PET, PP, etc.;

- bottles of edible oil, distilled water, cleaning and washing agents, cosmetics, medicines (except cytostatics), foodstuffs, etc. - labels: PE-HD, PE-LD, PP, etc.;
- glasses and jars of yogurt, cheese, etc. – with designation: PS, PP, etc.;
- packaging for various food products made of polystyrene (styrofoam) - with the EPS mark, etc.;
- multilayer packaging (carton for beverages),
- other plastic products: refreshment bottles, stoppers, plastic plates, cutlery, etc. – with following labels: PE-HD, PP, PVC, PS, PET, etc.;
- food cans and beverage cans.

The treatment process of packaging waste is similar with Spanish sorting plant (reception and storage, pre-treatment, sorting of materials, quality controls, adaptation of selected materials and rejected waste management).

Reception and storage: Packaging waste, collected through containers, is delivered to facility by cargo trucks. Upon acceptance of the waste, the mass of the waste received is determined and these data are recorded in the register of each type of waste received. After a visual inspection of the waste, the waste is unloaded from the truck and dumped in the waste storage facility according to waste categorization - types of polymer material, in primary tanks, bales or in piles.
Pre-treatment operation: After the waste is inspected and categorized, it is separated and stored according to the type of polymeric material and the type of packaging in which it is received, to prevent dust, noise, odors and other emissions from spreading. Transport of waste to and from storage is carried out by forklifts and with hand pallet trucks.

Sorting of materials, quality controls, adaptation of selected materials: The waste deposited in the reception area is collected with forklifts and delivered to the recovery line. The waste is fed into the inlet tank and then transported to the mill/crusher with vertical conveyor with the inlet feeder.
The mill/crusher shreds the waste into a 14 mm size fraction. The aim of shredding is to obtain a waste that is easier to clean in the further process of washing and cleaning the waste material. The crawler conveyor located at the outlet of the mill/crusher, transports the shredded plastic fractions to the centrifuge-operated washing machine. The centrifuge machine is used to clean the polymer material in such a way that at high speed, using centrifugal force, separation of impurities (less than 3 mm) from the polymer fraction occurs. Impurities such as dust or mud are separated by a perforated sieve.
After cleaning the waste in the centrifuge machine, the crushed and purified waste material enters the hydroseparation machine. In the hydroseparation machine, the waste material is immersed and cleaned with water, but the hydroseparator also serves to sort the waste. The plastic fraction as a lighter material floats to the surface and is transferred to the centrifuge machine via water and portable blades. Contaminants (heavier fraction) such as stones, metal, etc. end up at the bottom of the hydro separator. After the drying, waste is transported to the storage silos. Waste is than pressed into bales and suitable for further transport.

Rejected waste management: All the material that is not suitable for the recycling is transported to one of the Mechanical Biological Treatment Facilities in Croatia. The process of mechanical-biological treatment of mixed municipal waste begins with accepting the same in the receiving pit within the MBT building, after which the waste is shredded with primary shredder and the bio-drying boxes are filled.

When they have completed the biological drying process, which takes approximately 7-8 days, so that the waste is stabilized, it is extracted from the pits and moved to a mechanical treatment, where the fraction of 0-25 mm is first separated on the vibratory sieve, then the iron is separated and then nonferrous metals.

The following is the separation of inert heavy fractions by air separator, followed by the separation of PVC by optical separators. Waste is then shredded on the secondary shredders and thus it becomes SRF or RDF.

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