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Optimizing waste disposal costs of rental properties

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The subject of this paper is Optimizing waste disposal costs of rental properties. The goal of the study was to find ways to optimize and improve waste management and waste disposal costs in the rental properties selected for this study. The study was carried out for Y-foundation, the fourth biggest rental provider in Finland.

Ten locations were chosen, and waste container fill rates were observed for a selected duration of time. This gave insight on how waste is generated in rental properties, and how the housing types impact the results.

It was found that terraced houses generate more waste per tenant than apartment houses, and in both housing types the peaks of waste container fill rates are focused on the end of the month.

Recommended course of action could be coming up with key performance indicators, to help quickly ascertain the level of waste management in a rental property. Other proposed ideas include enhancing recycling awareness within tenants, monitoring waste disposal location usage in new properties to deduce if the waste facilities are sufficient, graduated moving days and a skip for for furniture disposal.

Keywords	Waste management, cost optimization

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Tämän työn aiheena on Vuokrakiinteistöjen jätekustannusten optimointi. Työn tavoitteena oli löytää keinoja optimoida ja parantaa vuokratalokiinteistöjen jätteidenkäsittelyä ja jätekustannuksia. Kymmenen kohdetta valittiin, ja niiden jäteastioiden täyttöasteita tarkkailtiin ennalta määrätyn ajan. Tämä antoi tietoa siitä, miten jätettä syntyy vuokratalokiinteistöissä, ja miten asuntotyyppi vaikuttaa tuloksiin. Tutkimuksessa kävi ilmi, että optimoimalla jäteastioiden määriä ja tyhjennystiheyttä voisi säästää huomattavasti jätehuollon kustannuksissa.

Hyviä toimintatapoja voisi olla tehokkuuden avainlukujen etsiminen, jotta kiinteistön jätehuollon taso olisi helppo päätellä. Muita ehdotettuja ideoita voisivat olla kierrätystietoisuuden lisääminen asukkaiden keskuudessa, uusien kohteiden jätetilojen käyttöasteen tarkkailemisen riittävyyden tarkistamiseksi, porrastetut muuttopäivät, sekä jätelava huonekaluille.

Keywords	Jätekustannukset, kustannusten optimointi

Contents

List of Abbreviations

KPI=Key performance indicator

1 Introduction

1.1 Background and previous papers on the subject

This paper focuses on analyzing waste management costs at rental properties. A selection of properties owned by the company Y-foundation, were served as a source for this data. The aforementioned Company is the client in this thesis.

1.2 Objective, thesis question and limitation of scope

The purpose of this paper is to find ways to optimize waste management in rental properties. This can be achieved through multiple means. One way is increasing recycling awareness amongst the tenants. This is difficult because people are unpredictable and have different motives and ambitions. Another way is analyzing the accumulation of waste and optimizing the management of it.

The importance of waste management should not be overlooked. The industry is big, and slow to adapt to new, innovative techniques. The goal of this paper is to find certain Key Performance Indicators that could be used in management of rental properties. These metrics can be used to improve the costs associated with waste management and generate savings and improvements. Saving money by optimizing is an opportunity for any company to improve their processes.

1.3 Structure of this thesis

This study comprises of ten chapters. The first chapter, the introduction, lays the basis for the background of the study and the objectives, as well as the scope and structure. The second chapter includes a brief word on the client company. The third chapter touches on legal terminology in Finland and general waste management info. The fourth chapter includes theory on cost optimization, metrics and key performance indicators. The fifth chapter briefly lists the most common types of waste collection currently in use in Finland. The sixth chapter discusses about the very topical subject of digitalization and

environmentalism from the view of waste management. The seventh chapter expands about the empirical study. The eight chapter lists the findings of this study. The ninth chapter is about the different costs of waste management. Tenth chapter is the conclusion. And finally, eleventh chapter is the recommended course of action chapter.

2 Y-foundation – the Client Organization in This Thesis

Y-säätio is the fourth biggest rental provider in Finland. They own over 17 000 apartments in over 50 cities, all over Finland. [Y-säätiö webpage, 2019]

Y-säätiö was founded in 1985, to answer the need for housing for homeless people. Their method was acquiring existing apartments and offering them as rental housing for homeless people. In 1985 there were almost 20 000 homeless people, 90% of them male. [Y-säätiö webpage, 2019]

The following excerpt from the company's website describes where the name of the company comes from and lists the founding members of the company:

> "Originally, the letter Y in the name of the foundation stood for the Finnish word *yksin*, 'alone'. It referred to the Y-Foundation's mission to help people living alone to find a home of their own.
>
> Today, the Y is thought to stand for *yhdessä*, 'together', in reference to Y-Foundation's extensive collaboration with other parties, both Finnish and international, as a part of its work to reduce homelessness."
>
> The founding members of the Y-Foundation are:
>
> The Association of Finnish Local and Regional Authorities
> The City of Espoo
> The City of Helsinki
> The City of Tampere
> The City of Turku
> The City of Vantaa
> The Church Council
> The Finnish Construction Trade Union
> The Finnish Association For Mental Health
> The Finnish Red Cross
> The Confederation of Finnish Construction Industries RT
> Alko Oy

For the purposes of this study, the Y-Foundation was interested in finding out efficient ways to optimize and improve waste management and waste disposal costs in the selected rental properties. To do this, the next section first looks into waste management in Finland. This is then followed by a discussion on cost optimization theory and Key Performance Indicators in Section 4.

3 Waste management in Finland

Waste management in Finland is regulated by a great number of different laws. The laws regulate which waste is considered which type, where they are to be disposed of, and which entity is responsible for the generated waste, just to mention a few. (Kojo, 2016)

3.1 Recycling Proficiency

In Finland, the percentage municipal waste amounts to of the total waste generated in Finland, is only 3%. Still, in 2014 this amounted to 2.6 million tons, which is a sizable amount. To landfills was delivered 460,000 tons, 856,000 tons were recycled, and 1.3 million tons were burned for energy. Recycling levels have been stagnating, but an upwards trend can be seen. The efficiency of how materials or energy are recovered from the waste is quite high, at 83%. (Kojo, 2016)

3.2 The laws concerning waste management in Finland

The following is an extensive collection of the important laws regarding the subject.

- Environmental Protection Act (527/2014, in Finnish, Finlex)
- Environmental Protection Decree (713/2014, in Finnish, Finlex)
- Waste Act (646/2011)
- Waste Decree (179/2012)
- Council Regulation establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC of the European Parliament and of the Council (NO 333/2011, EUR-lex)
- Reporting of data on municipal waste, construction and demolition waste and industrial and waste oils: Commission Implementing Decision (EU) 2019/1004 (EUR-Lex)
- Reporting of data on packaging and packaging waste: Commission Implementing Decision (EU) 2019/665 (EUR-Lex
- Government Decree on landfills (331/2013, in Finnish, Finlex)
- Government Decree on waste incineration (151/2013, Finlex)
- Government Decree on the recovery of certain waste in earth construction (843/2017, Finlex)
- Government Decree on batteries and accumulators (520/2014, in Finnish, Finlex)
- Government Decree on extractive waste (190/2013, Finlex)
- Government Decree on end-of-life vehicles and restrictions on the use of hazardous substances in vehicles (123/2015, in Finnish, Finlex)
- Government Decree on waste of electric and electronical equipment (519/2014, in Finnish, Finlex)

- Government Decree on the qualification requirements for equipment containing fluorinated greenhouse gases or ozone depleting substances (766/2016, in Finnish, Finlex)
- Act on restriction of the use of certain hazardous substances in electrical and electronic equipment (387/2013, Finlex)
- Government Decree on limiting the use of PCB-equipment and the processing of wastes containing PCBs (958/2016, in Finnish, Finlex)
- Government Decision on the separate collection and recovery of discarded tyres (527/2013, Finlex)
- Government Decree on the collection and recycling of wastepaper (528/2013, Finlex)
- Government Decree on packaging and packaging waste (518/2014, in Finnish, Finlex)
- Government Decree on the return system for beverage containers (526/2013, in Finnish, Finlex)
- Regulation (EC) No 1013/2006 (EUR-lex) of the European Parliament and of the Council on shipments of waste
- Council Regulation (EC) No 1420/1999 (EUR-Lex)
- Commission Regulation (EC) No 1418/2007 (EUR-Lex)

These laws are revised regularly to reflect the worldviews, for example the latest revision makes plastic packaging-bins mandatory, with a certain due date. Recycling should not be taken for granted, because previously it wasn't necessary to have all the different kinds of recycling bins, so these revisions are more often than not, good additions to the law.

3.3 Differences by area

The biggest differences in waste regulations concern the collection of plastic and packaging waste. Especially plastic recycling is a new thing, only emerging after 2016, whereas cardboard and metal recycling has been on the forefront since the 1990s. (Kaleva,2019)

3.4 Responsibilities

According to the Finnish law, the person responsible for arranging waste disposal is the person or entity in possession of said waste. This can be a private individual, property owner or enterprise. Municipalities and in some cases importers and manufacturers of some goods have a responsibility of managing the proper waste disposal.

Municipalities are responsible for arranging the disposal of municipal waste. Many municipalities employ regional waste disposal companies that often pay private companies to fulfil the legal responsibilities of the municipality.

Importers and manufacturers of certain goods also have a legal responsibility in disposing of waste that is generated by them, as in manufactured and imported by them. These are special kinds of products, and they include cars, batteries, electronics, and certain kinds of papers. The responsibility of the companies is to establish regional waste disposal locations for these kinds of products and materials. [Ympäristöhallinnon yhteinen verkkosivu, 2020]

3.5 Legal terminology

Following explanations come from the ministry of the environment of Finland. The terminology is based on legislation (Ministry of the Environment, Waste Act (646/2011; amendments up to 528/2014 included).

> 1) Hazardous waste means any waste with properties that render it flammable or explosive, infectious, or hazardous to human health or the environment in other ways, or with other corresponding properties (hazardous properties);
>
> 2) Municipal waste means waste generated in permanent dwellings, holiday homes, residential homes and other forms of dwelling, including sludge in cess pools and septic tanks, as well as waste comparable in its nature to household waste generated by administrative, service, business and industrial activities;
>
> 3)Mixed municipal waste means the municipal waste remaining after specific waste fractions have been separately collected at source;
>
> 43 a) household electrical and electronic equipment means electrical and electronic equipment used in a private household as well as electrical and electronic equipment of comparable quality and quantity used in commerce, industry, facilities and other activities; a piece of electrical and electronic equipment that is most likely used both in a household and in other activities is considered household electrical and electronic equipment; (410/2014)
>
> 4) Waste producer means anyone whose activities produce waste or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of such waste;
>
> 5) Waste holder means the waste producer, property holder or anyone in possession of the waste;

6) Property holder means the owner of a real property or the holder of the lease on the property;

7) waste carrier means anyone responsible for the transport of waste;

8) Waste broker means any undertaking who buys or sells waste, or brokers waste or waste management services on behalf of others, including such brokers who do not take physical possession of the waste;

9) Waste management means the collection, transport, recovery and disposal of waste, including monitoring and supervision of such operations and the aftercare of disposal sites, and actions taken as a broker;

10) Waste collection means the collection of waste at a reception point provided by the property holder, municipality, producer, distributor or other party, for on-site treatment or for the purpose of transportation for treatment, including preliminary sorting and temporary storage of waste;

10 a) separate collection of waste means the collection of waste where waste is kept separately by type and nature so as to facilitate preparation for re-use, recycling, other types of recovery or other specific treatment; (410/2014)

11) Reduction of the quantity and harmfulness of waste means activity, before a product becomes waste, that promotes the re-use of the product, extends its lifetime or prevents the generation of waste in other ways, or reduces the amount of harmful substances in the product, or reduces the harmful impacts on human health and the environment of the waste generated;

12) Re-use means re-using the product, or a component thereof, for the purpose for which it was originally conceived;

13) Preparing for re-use means checking, cleaning or repairing recovery operations, by which products or components of products are prepared so that they can be re-used without further pre-processing;

14) Recycling of waste means operations by which waste is reprocessed into a product, material or substance, either for the original or some other purpose; recycling of waste does not include recovery of waste as energy or the reprocessing of waste into fuel or material to be used for backfilling;

15) Recovery of waste means any operation whose principal result is waste serving a useful purpose in a production facility or elsewhere in the economy, so that it replaces other materials or objects which would otherwise have been used to fulfil a particular function, including waste being prepared to fulfil that function;

16) Disposal of waste means depositing the waste at a landfill, incineration without energy recovery, or some other comparable activity that does not constitute recovery, even where the secondary consequence of the operation is recovery of a substance, or of energy contained in the waste, including preparation of waste for disposal;

17) Waste treatment refers to the recovery or disposal of waste, including preparation for recovery or disposal;

18) Distributor of product means an undertaking who sells a product, or some other party that makes the product available to users.

These definitions are important from a legal standpoint, to specify what means what. They make sure that everybody is on the same page when talking about waste. They are also important for this study because the words are used often with no additional translations or definitions supplied later.

The following chapter goes into more detail about cost optimization theory and key performance indicators, to lay the foundation for the later analysis.

4 Key Performance Indicators

The following theories are excerpts from multiple studies. Often these terms are not used when talking about waste management, and very little could be found on them being used in waste management. This might change in the future, with waste being a big issue all over the world, and a big factor when combating environmental threats, which are at the forefront when combating climate issues.

What are Key Performance Indicators? Wayne W. Eckerson (2006) claims:

> A KPI is a metric measuring how well the the organization or an individual performs an operational, tactical or strategic activity that is critical for the current and future success of the organization.

In this study, fill rates of waste disposal facilities are used to determine how well the organization (apartments) perform an operational activity, in this case waste management. This might not be critical for the current or future success of the organization per se, but another thing to take into consideration could be the environment, e.g. the level of recycling achieved in the society. KPIs are measures of business drivers, and they can inspire operations that help fulfil strategic objectives of an organization. [Eckerson, 2006]

Because of this, KPIs are a good metric to utilize in businesses and apartments, regarding waste management. KPIs can also be used outside of business environments, for example in a project environment, such as optimization of waste management. [Kerzner, 2017]

Kerzner goes on to aptly describe KPIs:

> KPIs are high-level snapshots of how a project is progressing toward a predefined targets.

Key performance indexes can be a sum of many factors. For example, in this paper they could be the average waste costs per tenant in a certain apartment, multiplied by X. This paper reveals metrics that can be used to analyze waste management in the observed locations, such as the waste costs per tenant. These are merely metrics, but the

difference is that a KPI can be more abstract, being a formula combining multiple metrics that by themselves have no relation to each other.

The formula could be for example:

Waste costs per tenant + waste costs per apartment

The generation of KPIs is challenging for this example, because there are not enough varying metrics to consider due to the relatively low sample size and homogenous sampling. Only 2 locations had more than a single waste disposal location. KPIs can be quantitative or qualitative. In this study they would be quantitative, because they are based on raw numbers and not subjective things.

This study aims to optimize costs related with waste management. Cost optimization has terms related with it, that are important. A. Rajguru lists them as follows:

> Costing= Analysing expenses so it can be allocated to different processes, or services, or contracts, with the aim of ascertaining costs.
>
> Optimization=Optimization is a systematic effort made to improve profit margins and obtain the best results under given circumstances or situations
>
> Cost optimization= The Process of optimizing the expenses of cost in a project, from the starting of client's idea to the completion and final payment on site.

These have more to do with the original publication, which was related to construction projects, but they apply into cost optimization of waste management too.

The next chapter goes into detail about the different types of waste collection.

5 Types of collection

Urban residential waste can be collected using different methods. Most common way is the normal bin, which comes in different sizes. They are usually located near the property, either in a canopy, or a separate room inside the property. There can be more than one, depending on the size of the property.

5.1 Normal bins

From the bins that were gathered as data for this paper, it can be deduced that they are easy to use and already familiar to most people. They are cheap to manufacture and have an established reputation as being the norm, on what a waste disposal storage device looks and seems like. The bins are rather easy to empty, being somewhat light and equipped with wheels, by waste disposal personnel.

Disadvantages include the covers that they have are entirely reliant on the ability of the people using them, if tenants leave them open, rat infestations could occur. They are sometimes overfilled due to tenants lacking the ability to look at the neighboring bins and checking their fill rate status. It was observed during this study that when people see one full bin, they instantaneously assume the fill rate statuses of the other bins. Leaving them empty and overfilling the first one. The plastic of the bins is vulnerable to dings and crashes, especially the front of the bin that has the infographic displaying what the contents should be, what is allowed and what is unallowed inside the particular bin.

5.2 Deep collection method

Molok-containers are widely used in Finland. How they work is quite different from normal bins. A deep hole is made in the ground, and a canopy placed on top of it. Inside is a large bag that holds all the waste. When the time comes and it is full, a crane-equipped truck comes and pulls the inside bag out of the ground. Visually, it is mostly underground then.

Image 1. Picture of Molok containers.

In image 1 there is an example of a deep collection system. There are different types of these systems and they are widely used in Finland. They are installed by making a large hole in the ground. On the bottom of this hole a well is installed and covered with an enclosure. The parts above ground level are covered. Inside the enclosure is a bag that contains all the waste. The emptying is done by means of a crane-equipped truck. This truck pulls the inside bag from the enclosure. Because of this the area around the containers must be free of obstacles, so the truck can be parked next to the containers. This removes the possibility of them being inside for example.

This method is quite cheap, because trash may be emptied less often, and they are only emptied when the container bag is full. The inside bag is quite big, five cubic meters, which is bigger than most normal bins. They employ gravity to crush the waste inside to be denser. They are odorless because of the large cover that hides the waste disposal hole.

Molok containers are susceptible to rodents due to the thin exterior of the container “bag”. They are also unlocked, because they must be outside, to be accessible for the truck that comes to empty them. This means that non-residents can use them too. New models can be fitter with locks, though. They also have an element of danger, because of the large size, and the deepness of the insides if someone falls in them

5.3 Additional types

Image 2 shows there is an example of an automatic tube collection system that is located in Suurpelto. It is in use in many places in Finland already. For example, the city districts, Kruunuvuorenranta, Jätkäsaari, and Kalasatama employ it currently.

The basics of the automatic waste disposal system is that a tube runs from the place where the waste is disposed, to a place where it is centrally collected. In the tube system, this is done via the tubes being underpressurised.

This method cuts down on emissions by having less garbage truck-traffic. Trucks will not be driving through narrow streets, causing danger to children and spewing emissions. The removal of truck-traffic improves the air quality. It is also invisible in the street view, odorless and automatic. (Iltasanomat, 2011)

Disadvantages include reported problems with rats and costs. Due to being a relatively new technology, early adopters pay the brunt of the development. (Helsingin Sanomat. 2019)

Image 2. Picture of Tube station

5.4 Smart waste disposal facilities and Digitalization

Digitalization can be utilized in the waste disposal industry as with almost every industry. IoT could mean big things for the waste industry, automating collection and recycling for example. Smart disposal facilities have begun to appear as of late. These employ various differing methods of making them “smart”. These include using solar energy to power them or using trash compactors (on a small scale) to fit more waste inside them.

For example, in developing countries such as Cambodia, it is impossible to go a day without producing waste, according to Lilli Albrecht:

> It is common practice to use plastic bags for every little purchase; water is mainly sold plastic bottles which are commonly thrown away after a single use. Unless one actively guards against it, it is nearly impossible to go a day in Cambodia without producing waste.

She also expands on one of the hardest problems to solve in waste management, human willingness:

> However,due to to the poor economic conditions of many Cambodian citizens there is a general unwillingness to pay for waste collection services and a lack of awareness about the importance of sustainable, functioning waste management system. Many people do not understand the importance of proper waste collection and disposal and still throw their trash haphazardly around collections points or burn their trash on the street.

Even though Cambodia could be seen as an extreme case to bring out as an example, the same problem persists everywhere else too. Waste disposal is a game of consciousness and convenience. Most people want to do the right thing, but most are only ready to do it when it convenient or easy enough. This was seen in the data gathered also, with some apartment locations being more environmentally conscious than the others. This is not just a coincidence. Digitalization could be a tool to bring more convenience into the waste disposal industry. Smart bins are one way to bring the waste industry to the century we are currently living in. They allow the optimization of the emptying of the bins, by means of submitting data using various sensors. Things such as is the bin full or what kind of waste is located inside of it. This is already utilized to some extent in Finland, in the Molok-container system. Applications for smart phones are another thing that could be used to solve problems, due to their commonness. They could even be a new medium in which to promote recycling, but things such as a way for waste companies to improve their customer relations management. Giving information on waste pick-up times and such could be useful. Smartphones are also an excellent way to collect data on waste disposal behaviors, such as how much waste is generated and such. Education is another tool the smartphones could be utilized in, raising recycling awareness through mobile games and such. (Lilli Tabea Albrecht, 2018)

5.5 Foreign methods

The waste management policy, which has been adapted in Germany over the past 20 years, is based on closed cycles and assigns disposal responsibilities to manufacturers and distributors of products. This has made people even more aware of the necessity to separate waste, led to the introduction of new disposal technologies, and increased recycling capacities. Today, 14 per cent of the raw materials used by the German industry are recovered waste. Modern closed cycle management contributes, with a share of

approximately 20 per cent, to achieve the German Kyoto targets for the reduction of climate-relevant emissions. (M. Nelles 2015)

The following factors, according to M. Nelles, contribute to lessen the environmental impact of both household waste and heavy industry:

> Closed cycle management is not only a contribution to the environmental protection, it also pays off economically. The waste management industry has become an extensive and powerful economic sector in Germany: almost 200,000 people are employed in approximately 3,000 companies which generate an annual turnover of approximately 40 billion euro. 15,000 installations contribute to resource efficiency by recycling and recovery procedures. High recycling rates of approximately 60 per cent for municipal waste, 60 per cent for commercial waste, and 90 per cent for construction and demolition waste speak for themselves.'

As per the previous quote, recycling is not only beneficial to the environment, but to the economy as well.

> Waste management was under a radical trans-formation since the early Seventies. At this time every village and town had its own tip (some 50,000 of them in total); today untreated domestic and commercial waste can no longer be deposited at landfill sites.

As was discussed previously, waste management legislation has been under constant change for a long time, with new regulations coming into effect, as the importance of proper waste management has been realized. These are good changes when thinking about the environment, and the waste industry will continue to improve its procedures no doubt.

> The European Union aims at the same conditions in the Member States. Both the living conditions and the methods of disposal are still quite different.

Within the European Union, differences in waste management standards still exist. Proper waste management is more expensive and takes care and consideration, as opposed to using landfills where everything is disposed of without recycling.

> Article 4 of the revised EU Waste Framework Directive (Directive 2008/98/EC) sets out five steps for dealing with waste, ranked according to the environmental impact – the “waste hierarchy”.

> The Waste Hierarchy gives top priority to preventing the creation of waste in the first place. When waste is created, it gives priority to preparing it for re-use,

> recycling, other recovery (such as energy recovery) and disposal (landfill after pre-treatment) in descending order of environmental preference.

The same waste hierarchy is in use in Finland. This minimizes the amount of waste going to the landfills, making sure that all materials have been taken advantage of to the highest precision. This has reduced the amount of waste going to the landfills. This is a natural progression in a country seeking to improve their waste management. Over-reliance on landfills changes to recycling, which is a great step towards a better, cleaner environment.

> The amount of waste currently produced is still too high. In particular in the field of municipal waste, further efforts towards a resource efficient consumption are needed to prevent waste from arising. The German waste prevention programme, launched in 2013, will contribute to develop advice, support, and incentive measures.ġ 2013, there were only minor changes in the waste composition.

The amount of waste rises as the population rises, which happens everywhere, but especially in the developing world. This creates a health hazard for the inhabitants in these countries as well. (N. Ferronato, 2019)

Germany is a prime example to compare to because they have a very high recycling rate. In 2013, of 49,570 million tons of municipal waste, 87% was recycled. In Finland, this number was 83%. This means waste that is either recycled or incinerated for energy, as opposed to delivered to a landfill. (M. Nelles, 2015)

In Europe this recycling average, albeit with the data being from 2012, was only 32%. The recycling numbers for Germany and Finland were 64% and 33%, respectively. Likely this has gone up in many countries, not just in Finland and Germany since then. (Eurostat, 2012)

5.6 Environmental issues

Waste disposal is a very big environmental issue. Recycling is an important aspect in achieving greener societies. In developing countries much of the environmental problems can be linked to recycling. Poisonous rivers, hygiene problems and spreading of diseases can all be traced back to lacking waste disposal systems. Plastic is an issue in the developing world because it is a very cheap material to use, but not very well

recycled. Especially in the developing countries where the public awareness and funding for that sort of thing are lackluster at best.

In Finland new bins have been supplied in many locations, to be used for plastic packaging waste, they are cheap to use, because the costs are lower than they are in mixed waste disposal. The waste disposal companies have an incentive to use them because it is easier to dispose of this way. Most of the locations chosen for this empirical study, for which the data is presented next, already had the aforementioned plastic collection bins.

In the following chapter we see the methods used in the empirical study, and a deeper look into waste management in Finland, from a closer perspective.

6 Empirical study

Source of the data to be analyzed was on-site visits on different kinds of locations. These visits were made between September and October. A wide variety of apartment-types and cities, as well municipalities, were chosen to maximize the usability of the data, and the possibility of applying it in differing locations. On-site visits consisted of traveling to location, taking pictures of the fill-rate of waste management facilities, and then transferring the info to a sheet-software. The estimation of the fill-rate was done by eye, but the innards of the waste storage bins provided a clear basis on which to base the numbers on. The dates of the visits were pre-determined. Each location, of which there 10 of, was visited 4 times. These were as follows: beginning of month visit, middle of the month visit, and 2 visits in between. This maximizes the accuracy of the data gathered.

6.1 Objectives

The objectives of this paper were clear, to find indications that waste management in the target locations has room for improvements, and to prove this using mathematical analysis.

KPI´s are the wished-for result that could be used to generalize and help guide real estate companies and help them achieve better success in optimizing waste management within their holdings. This is achieved by for example supplying technical housing managers with the necessary information, and them doing the local work from a lower level. This could result in big savings, with the cost savings coming from the groundwork done by housing managers. Giving them these KPI´s would give them something to aim for if the waste management costs are not in line with comparable apartment types.

By highlighting and comparing the waste management and circulation economy situations of other countries, we can objectively compare foreign methods to the Finnish model, on a surface level. The surface level is the only point we can achieve due to there being no fitting data available for the purposes of this study.

This study proposes ideas that could be implemented with digitalization and in turn improve the environment. If the methods used could be automated through the means of

digitalization, the whole process of optimizing waste management costs could be streamlined by a large degree. This would decrease the man hours spent by the lower level employees on doing the groundwork and make it possible to manage the waste management optimizing from a higher level, thus achieving a better perspective on which to start even company-wide optimization and innovation. Achieving better waste management would limit carbon dioxide pollution caused by waste logistics, improve recycling and thus better the flow of materials and make investing the saved money in optimizing into more green technology possible.

6.2 Methods and data collection

Locations were chosen based on a wide selection of different apartment building types, with differing amounts of people living in them. It was also taken into consideration the type of placement of the bins the apartments had.

Chart 1. List of locations observed for this study

Location	Number of apartments	Apartment type
Vantaa		
Sorakuja 5	55	Apartment house
Puunhaltijankuja 1-3	72	Apartment house
Ryytimaantie 2	11	Terraced house
Helsinki		
Agronominkatu 1	66	Apartment house
Norkkokuja 3 ja 4	61	Apartment house
Ränkitie 1-3	63	Terraced house
Espoo		
Kalastajanmäki 3	69	Apartment house
Kaskimaa 4	54	Terraced house
Leppäviita 1 ja 5	43	Apartment house
Viittakorpi 2	39	Terraced house

6.3 Visual reviewing of fill rate

The fill rates of the bins were measured visually, due to there being no better way to do it. The present method consisted of picture taking, on-site and later analysis of the pictures.

As an example, pictures of every fill rate, in increments of 10.

Image 3. Fill rate of 10% (Puunhaltijankuja 1 ja 3, 07.11.2019)

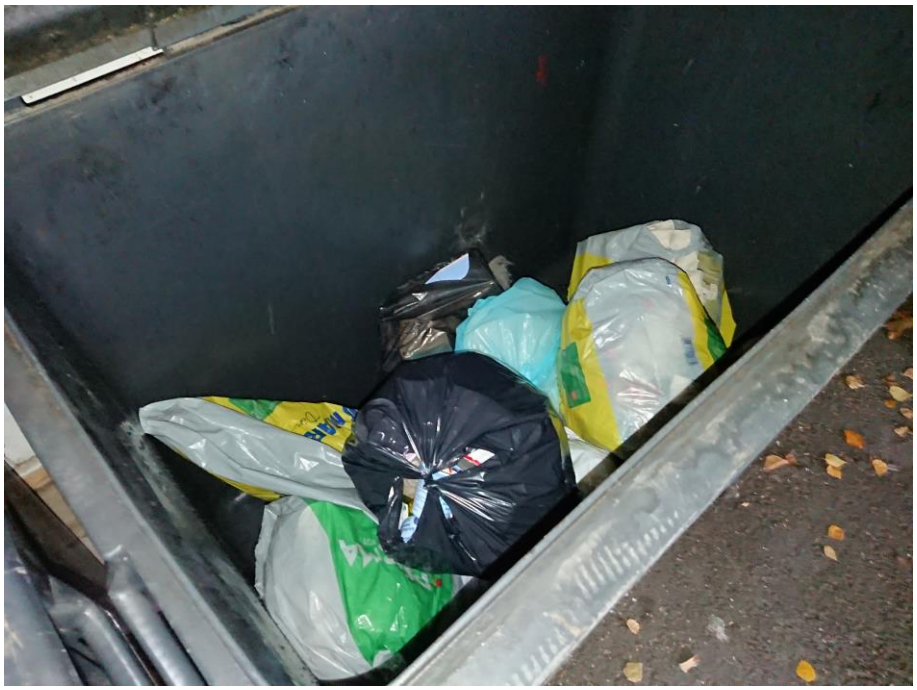

Image 4. Fill rate of 20% (Kaskimaa 4, 17.10.2019)

Image 5. Fill rate of 30% (Kalastajanmäki 3, 07.11.2019)

Image 6. Fill rate of 40% (Kalastajanmäki 3, 19.09.2019)

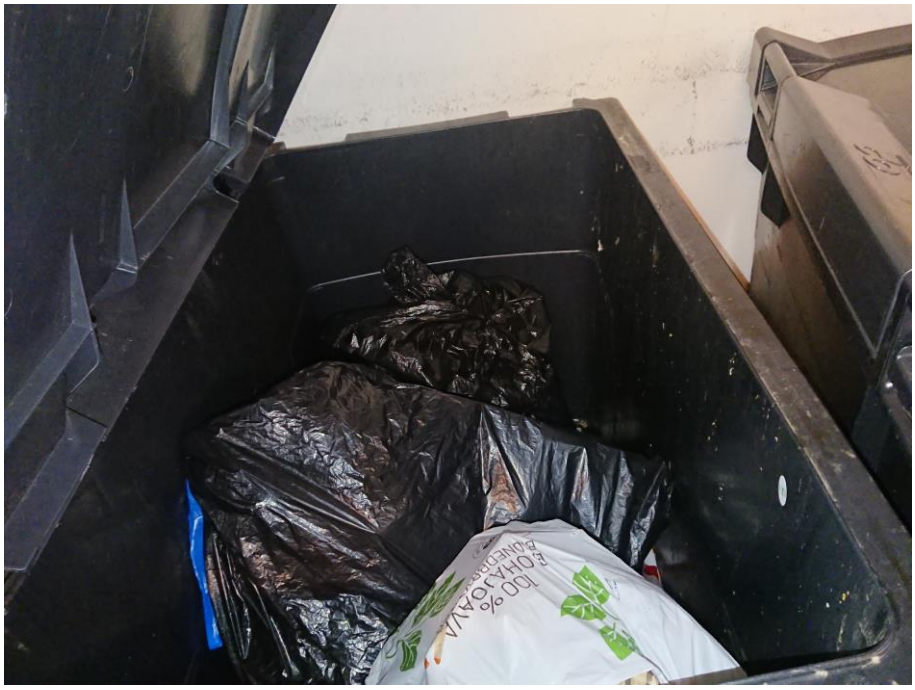

Image 7. Fill rate of 50% (Agronominkatu 1, 16.10.2019)

Image 8. Fill rate of 60% (Kaskimaa 4, 07.11.2019

Image 9. Fill rate of 70% (Leppäviita 1, 30.09.2019)

Image 10. Fill rate of 80% (Norkkokuja 3, 18.09.2019)

Image 11. Fill rate of 90% (Norkkokuja 4, 18.09.2019)

Image 12. Fill rate of 100% (Ränkitie 1-3, 17.09.2019)

6.4 Costs

The deep collection method (Molok) requires regular upkeep of the inside bags, lest they break. Waste disposal rooms require regular cleaning, as do the waste bins. The automated waste disposal method is quite expensive to repair and upkeep. For the purposes of this study the costs of these factors were not taken into account, due to there being no accessible data easily available on them.

6.5 Collection method

The costs of waste management can be analyzed using different factors. Different buildings have differing amounts of people residing within, different amounts of apartments and range in the amount of livable space inside.

Costs were analyzed per tenant, per apartment, and per square meter. This wide range gives better insight into the costs. Normal waste container costs were analyzed more in depth later in this study, this is because they were the focus of the study. The other

methods of waste collection were considered to serve as a baseline and to have something to compare the normal bins to. Because this study mainly focused on the normal bins, the data that was gathered about them was far more extensive compared to the data that was available about the other waste collection methods, used as a baseline for this study.

This analyzing yielded results that clearly shows the differences between methods of garbage disposals. Notable is that the data is based on information from the year 2018, as opposed to the year of 2019. This is because at the time of this study being started, it was the year 2019. The waste costs for locations with normal bins were readily available but his was not the case for the other waste collection method-locations.

Observed locations for the automatic collection method were Piilipuuntie 7, Piilipuuntie 9, and Piilipuuntie 11.

Chart 2. Data of Piilipuuntie 7

Piilipuuntie 7	
Number of apartments	75
Tenants in total	126
M^2 in total	3965,5 m^2
Waste costs in 2019	21 910,80 €
Per apartment	173,90 €
Per tenant	292,10 €
Per m^2	5,50 €

Chart 3. Data of Piilipuuntie 9

Piilipuuntie 9	
Number of apartments	60
Tenants in total	111
M^2 in total	3284,5 m^2
Waste costs in 2019	19 641,60 €
Per apartment	177,00 €
Per tenant	327,40 €
Per m^2	6,00 €

Chart 4. Data of Piilipuuntie 11

Piilipuuntie 11	
Number of apartments	64
Tenants in total	128
M^2 in total	3516 m^2
Waste costs in 2019	18 451,20 €
Per apartment	144,20 €
Per tenant	288,30 €
Per m^2	5,20 €

The example of an automatic waste collection chosen for this study is at Piilipuuntie, in the city of Espoo. The costs per tenant were between 144 euros and 177 euros per tenant. Per apartment this rises from 288 euros up to 327 euros per apartment. Waste costs per square meter of livable space are 5-6 euros.

Chart 5. Data of Lyhtykuja

Lyhtykuja	
Number of apartments	58
Tenants in total	106
M^2 in total	3259,5 m^2
Waste costs in 2019	4 817,10 €
Per apartment	83,10 €
Per tenant	45,40 €
Per m^2	1,50 €

At Lyhtykuja, which was the deep waste collection method chosen as an example for this study, the prices were 45.4 euros per tenant regarding normal household waste. Per apartment the price is 83 euros per apartment. Per square meter of livable space, the price is 1.5 euros. This is a marked decrease in price compared to the automatic waste collection system.

Chart 6. Normal waste container averages

Normal waste container location averages	
Number of apartments	53,3
Tenants in total	110,6
Waste costs in 2019	5 173,50 €
Per apartment	104,04 €
Per tenant	47,62 €

What can be deduced from the charts detailing the costs of different waste collection systems is that the deep collection methods is the cheapest. This is offset by the fact that it has more problems associated with it, as detailed in an earlier chapter. Also, the building costs are higher. Then again, the automatic waste collection method is by far the most expensive, but also has many benefits. When choosing a waste collection method for a new building, many things have to be taken into consideration. The next chapter details the findings of the empirical study.

7 Findings

Out of the ten observed locations for this study, two locations had two separate canopies for waste disposal. The rest had one location for waste disposal, either a waste room inside the building or a waste canopy outside the building.

At one of the locations they had two places for the waste to be deposited in. One of them was well utilized, but the other one was almost empty (Image 13). This was observed in the other terraced house locations too, people have a preset routine already, which means they will always use the same location to dispose of their waste. In the terraced house locations, the waste rooms are located next to the parking lots, and this could also be the reason people use one over the other. The people using them have differing amounts of waste or possibly the people near the other waste room do not bother walking to the unused one, preferring to dump their waste on their way to the car.

Almost all the locations had the same problem: fill rates exceeding the maximum capacity of the waste bins at the end of the month. Other times the fill rates were within the limits

of the capacities of the bins. This is not only costly, but also inefficient. The municipal agency of waste disposal, HSY, does not disclose the amount of waste collected. They only disclose the amount by filled containers. Thus, an empty container is 100% filled according to HSY's numbers, which is counterproductive. This means that properties generate massive amounts of waste on paper, even if the collected bins were to be empty. This in turn means the rental properties (or their owners) are paying huge sums for essentially nothing. This discrepancy cannot be observed though, without someone physically going to the location and observing it, with regular intervals to see the difference. In contrast, Molok disposal bins are weighed and then the customer is billed for trash collected and not just a flat sum.

Image 13. Waste canopies (red dots) at location Viittakorpi 4.

Image 14. Situation in a waste room at the end of the month.

The following chapter provides the numerical data. The acronyms for the visits mean chronological order. 1st visit is between start of the month and the middle, 2nd visit is middle of the month, 3rd visit is between middle of the month and end of the month, and 4th visit is at the end of the month.

Some of the locations were part of the so-called Ekokompassi initiative, which aims to increase recycling awareness and recycling at apartment houses. This can be seen especially at Norkkokuja, in Viikki. They have a proven track record of excellent recycling. This can also be attributed to an active community interested in environmental issues, which Norkkokuja most certainly has. The location is also close to nature which adds to the peoples wilingnessl to improve their own quality of life (clean waste disposal facilities). Then again, Sorakuja, which is in Vantaa is also part of the same Ekokompassi initiative and their recycling and waste disposal habits are far worse as can be deduced from the data.

One way to increase recycling is adding shelves for items that can be used by other people in case not needed by the previous owner. This eliminates the need for them to be thrown in the trash. This is useful especially with books and some electronics also.

7.1 Agronominkatu 1

Apartment house located in Viikki, a district in Helsinki. 66 apartments in total, with a waste room. Total of 118 tenants. Number of mixed waste trash cans is 5.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
28%	48%	31%	94%

As seen from the data, end of the months fill rate is much bigger than the other months. Making assumptions from these fill rates, 6% of the bins in this location could be removed.

If optimization was done flexibly, the second highest fill rate was only 48%. Removing end of the month fill rate from the equation, the average fill rate of the 3 remaining observations is only 35.6%. If additional bins were supplied in preparation for the end of the month, even more money could be saved.

Additional costs were also incurred by loose waste in the waste canopy. This amounted to 308 euros which is a considerable amount. This could be furniture and such, and a solution for this would be increasing the recycling awareness of people with info in the waste disposal location, or additional waste disposal space being available at the end of the month. People tend to dump furniture in the waste locations when moving to a new house, so this is a difficult problem to solve.

7.2 Kalastajanmäki 3

Apartment house located in Tiistilä, a district in Espoo. 69 apartments in total, with a waste canopy. Total of 130 tenants. Number of mixed waste trash cans is 8.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
65%	87.5%	58.75%	50.625%

This location is not in line with the others, with the middle of the month having the largest fill rates. Even then, 10 percent of the capacity could be removed.

Total waste collected (not weighted): 15,984 kilograms of mixed household waste. Kaskimaa 4

A terraced house complex located in Latokaski, a district in Espoo. 54 apartments, with a waste canopy. Total of 134 tenants. Number of mixed waste trash cans is 5.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
21%	14%	36%	74%

As seen from the data, end of the months fill rate is much bigger than the other visits. Making assumptions from these fill rates, one quarter of the the bins in this location could be removed.

If optimization was done flexibly, the second highest fill rate was only 36%. If additional bins were supplied in preparation for the end of the month, even more money could be saved. Additional costs were incurred by loose waste in the waste canopy. Average fill rate with the 4th visit not considered was only 23.6%, compared to the 36.25% when it was included.

7.3 Leppäviita 1

Apartment house located in Leppävaara, a district of Espoo. 43 apartments, with a waste room. Total of 86 tenants. Number of mixed waste trash cans is 4. The location has

places for passing on usable equipment (shelves) but still often had furniture and other pickable trash.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
7.5%	40%	65%	90%

As before, it can be seen from the data that the end of the months fill rate is much bigger than the other visits. Making conclusions from these fill rates, one quarter of the the bins in this location could be removed.

Average fill rate of the trash bins was 50.6%. Not taking the end of the month visit into account brings the average to 41.25%.

7.4 Norkkokuja 3

- Viikki (61 apartments, apartment house, jätekatos (2))

Total of 149 tenants.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
70%	58.3%	45.8%	65%

The location at Norkkokuja is one of the apartments taking part in the Ekokompassi-recycling awareness program. This shows, with the amount of mixed waste being very reasonable, and all other recyclables being well utilized. If all waste is recycled well, there will not be much mixed waste. Most of mixed waste is plastic anyway, and with the advent of the plastic packaging bins, mixed waste is getting more unused.

As can be deduced from the data, there is a surplus of 30% that could be cut, according to our limited dataset. Looking at the data, the fluctuations in the data are far lower than in the other locations. Removing the highest average result gives the average of 56.4 percent which is just 3.4 percent lower than the combined average. In the other locations this was often over 10 percent.

7.5 Norkkokuja 4

- Viikki (61 apartments, apartment house, jätekatos (2))

149 tenants.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
65%	62.5%	52.5%	67.5%

The location at Norkkokuja is one of the apartments taking part in the Ekokompassi-recycling awareness program. This shows, with the amount of mixed waste being very reasonable, and all other recyclables being well utilized. If all waste is recycled well, there will not be much mixed waste. Most of mixed waste is plastic anyway, and with the advent of the plastic packaging bins, mixed waste is getting more unused.

As can be deduced from the data, there is a surplus of 32.5% that could be cut, according to our limited dataset. Looking at the data, the fluctuations in the data are far lower than in the other locations. Removing the highest average result gives the average of 60 percent which is just 1.9 percent lower than the combined average. In the other locations this was often over 10 percent.

7.6 Puunhaltijankuja 1 ja 3

- Leinelä (72 apartments, apartment house, waste room)

A terraced house complex located in Leinelä, a district in Vantaa. 72 apartments, with a waste room. Total of 131 tenants. Number of mixed waste trash cans is 3.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
23.75%	100%	28.75%	117.5%

As seen from the data, end of the months fill rate is much bigger than the other visits. The fluctuations in this location are bigger than in some of the other observed locations. A reason for this could be higher turnover in the the tenants. This location was one of the biggest observed with the most tenants, so people are more likely to move in and out than in some of the other locations observed in this paper. The waste room contained things that were not put into bins, this phenomenon was observed almost every single visit. This usually means tenants moving out and having knowledge where to dispose of furniture, for example.

If optimization was done flexibly, the second highest fill rate was only 36%. If additional bins were supplied in preparation for the end of the month, even more money could be saved. Additional costs were incurred by loose waste in the waste canopy. Average fill rate with the 4th visit not considered was 50.8%, compared to the 67.5% when it was included.

7.7 Ryytimaantie 2

Terraced house complex located in Hämeenkylä, a district of Vantaa. 11 apartments, with a waste canopy. Total of 31 tenants. Number of mixed waste trash cans is 3.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
43.3%	33.3%	45%	60%

Moderately sized terraced house complex. Suspected low turn-over of tenants so average fill rates could be easily predicted. Average fill rate of 45.4% so over half the capacity goes unused, this would mean removing one trash can, reducing the mixed waste costs by 33.3%.

7.8 Ränkitie 1 ja 3

Terraced house complex located in Ala-Tikkurila, a district of Vantaa. 63 apartments, with 2 waste rooms. Total of 149 tenants.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit
15%	76%	35.5%	71%

The fluctuations in this location are bigger than in some of the other observed locations. The location is a terraced house. The end of of the month visits fill rate was lower than the second visits, which is not inline with the majority in this study. Still, major savings could be had because the highest fill rate was only 76%, with the average fill rate being only 49.4%.

7.9 Sorakuja 5

Simonkylä, 55 apartments, apartment house, jätekatos

An apartment house complex located in Simonkylä, a district in Vantaa. 55 apartments, with a waste canopy. Total of 81 tenants. Number of mixed waste trash cans is 3.

The averages for the different visits were:

1st visit	2nd visit	3rd visit	4th visit

66.7%	120%	58%	23%

The fluctuations in this location are bigger than in some of the other observed locations. A reason for this could be higher turnover in the the tenants. This location is an apartment house with a large number of tenants, so people are more likely to move in and out than in some of the other locations observed in this paper. The waste room contained things that were not put into bins, this phenomenon was observed almost every single visit. This usually means tenants moving out and having no knowledge where to dispose of furniture, for example.

If optimization was done flexibly, the second highest fill rate was only 66.7%. If additional bins were supplied in preparation for the end of the month, even more money could be saved. Additional costs were incurred by loose waste in the waste canopy. Average fill rate with the 4th visit not considered was only 49.4%, compared to the 67% when it was included.

7.10 Viittakorpi 2

- Nöykkiö (39 apartments, terraced house, jätekatos (2))

Total of 97 tenants.

Canopy number 1:

1st visit	2nd visit	3rd visit	4th visit
40%	**40%**	**33.3%**	**110%**

Canopy number 2:

1st visit	2nd visit	3rd visit	4th visit
15%	**13.3%**	**10%**	**53.3%**

And combined averages of:

1st visit	2nd visit	3rd visit	4th visit
27.5%	**26.65%**	**21.65%**	**81.65%**

As can be seen from the data, the other waste canopy is almost completely unutilized, and the other is used not as well as intended. This could be a result of a miscalculation from HSY´s part, or statistical anomalies. Removing the end of the month fill rate numbers results in a fill rate average of 25.3%.

7.11 Summary

The waste disposal facilities are not optimally used. During the last visit at the end of the month, the waste disposal locations were vastly more utilized, as compared to the beginning of the month. This imbalance is hard to rectify, but it can be done. The following charts and images reveal this in a more graphic way than just using numbers.

Chart 7. Mixed waste bin fill-rates at different locations

Location	1. visit	2. visit	3. visit	4. visit
Agronominkatu 1	28,0	48,0	31,0	94,0
Kalastajanmäki 3	65,0	87,5	58,8	50,6
Kaskimaa 4	21,0	14,0	36,0	74,0
Leppäviita 1	7,5	40,0	65,0	90,0
Norkkokuja 3	70,0	58,3	45,8	65,0
Norkkokuja 4	65,0	62,5	52,5	67,5
Viittakorpi	27,5	26,7	21,7	81,7
ryytimaantie	33,3	60,0	43,3	45,0
Puunhaltijankuja 1 and 3	23,8	100,0	28,8	117,5
Sorakuja 5	23,3	58,3	66,7	120,0
Ränkitie 1-3	15,0	76,0	35,5	71,0
Average	34,5	57,4	44,1	79,7

*The order numbers of the visits correspond to the order in which they were visited. First visit is between the beginning of the month and the midpoint of the month. Second visit is

the midpoint of the month. Third visit is between the midpoint of the month and the end of the month. Fourth visit is the end of the month.

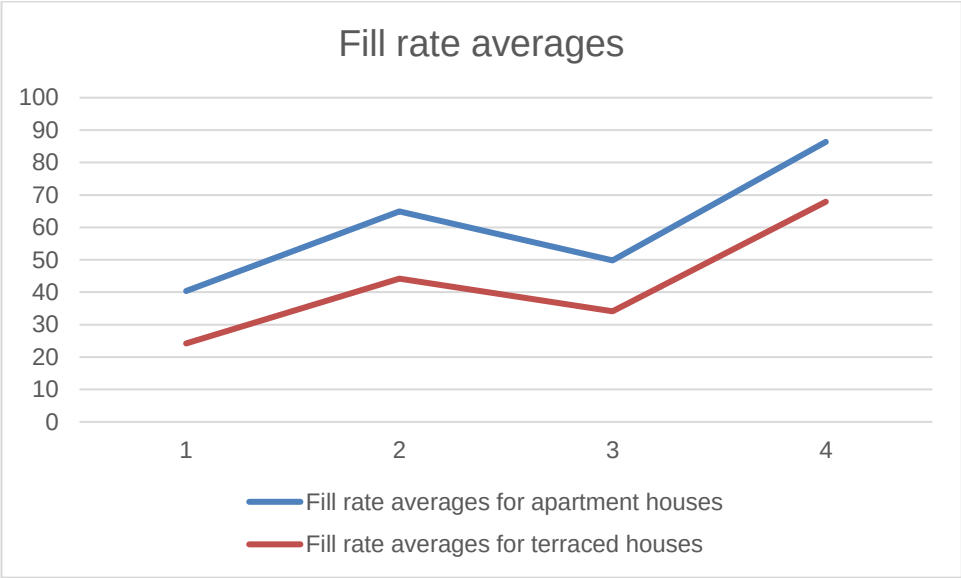

Image 15. Fill rate averages.

Picture 15 confirms the hypothesis that waste production (or disposal of said waste) is heavily focused to the end of the month, with the midpoint of the month also being an outlier.

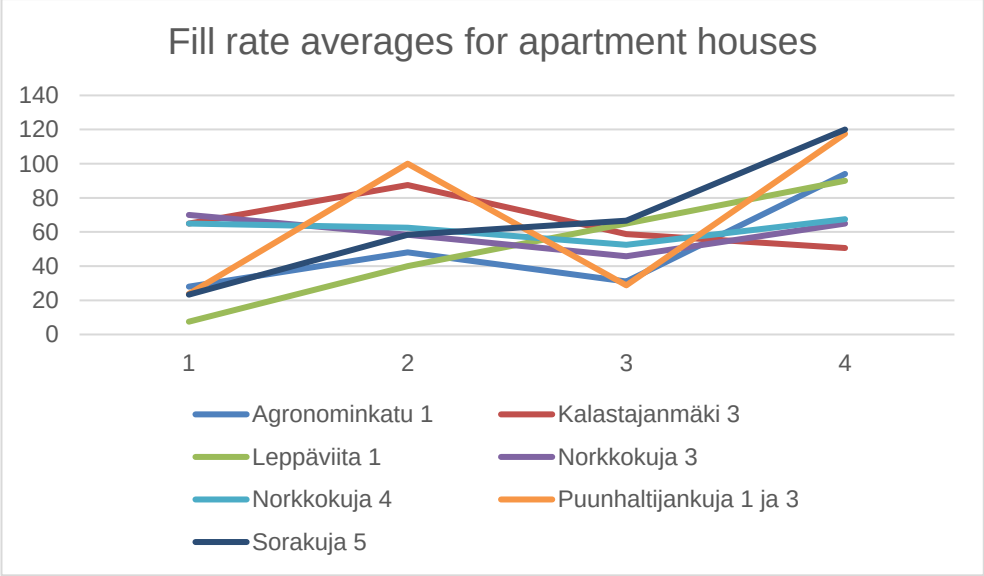

Image 16. Fill rate averages for apartment houses.

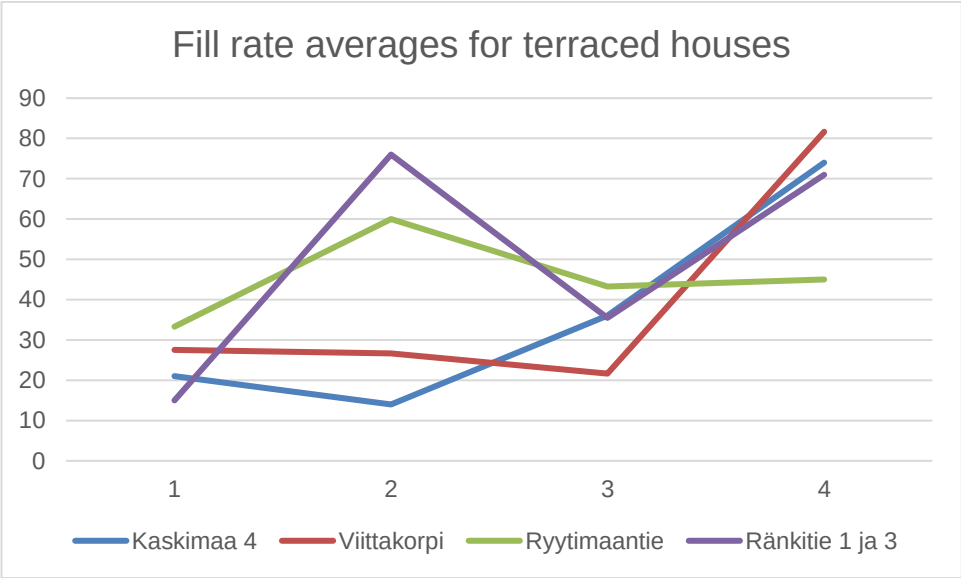

Image 17. Fill rate averages for terraced houses.

As can be seen from image 17, the scale does not even reach 100%. This is because the average fill rates were never over 90% even. Whereas the corresponding image for the apartment houses goes to 140% (because in some cases the averages reached 120%). Picture 17 highlights weaknesses in the data collection method used in this study. Due to the limited number of visits that were made, some locations differ from the main-stream and maybe do not represent the truth.

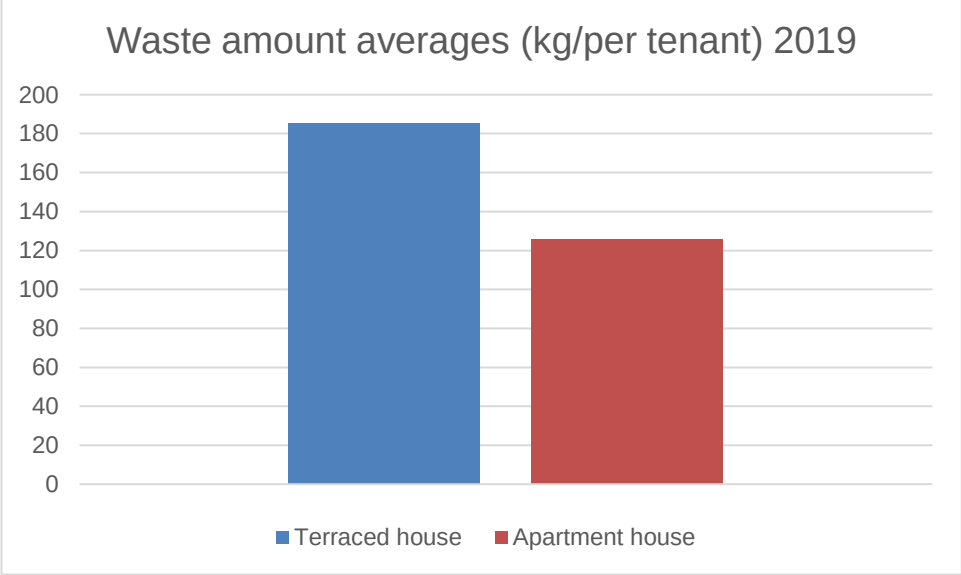

Image 18. Waste amount averages.

Image 18 about waste amount averages clearly highlights how much more waste is generated in terraced houses as compared to apartment houses. This could be the sum of many factors, such as terraced houses having more tenants per apartment, the figures being 2,5 tenants per apartment in terraced houses, and 1,9 tenants per apartment in apartment houses, in the locations observed in this study. Percentually this is an increase of 31.5 percent in tenants per apartment which is not insignificant.

8 Costs

When analyzing the costs of different methods of waste disposal, it was found that there are marked differences in the prices. The methods they were analyzed by were per tenant, per apartment, and per square meter. In the end this did not have any effect because they all had the same result, which is that the centralized method of tubes is by far the most expensive.

The bills collected as data for this, were comprehensive accounts about the waste disposal costs at differing locations. The year 2018 as well as the year 2019 were chosen as the basis for this data to add reliability. The costs were provided by HSY, from their website.

The method on what to base the cost savings is more difficult to determine. **Different methods could on the averages of all visits on all locations**, or all visits on one location, or an average of a specific visit on all locations (for example the 4th visit having average fill rates higher than the other visits), comparing terraced houses and apartment houses and a multitude of others.

8.1 Per location

Agronominkatu 1 (5 mixed waste trash cans)

The mixed waste costs for 2018 were 6,785 euros , plus bin rental for 149 euros. Other costs were 308 euros. Total waste collected (not weighted): 22,680 kilograms of mixed household waste. Costs per apartment were 109,7 euros. Costs per tenant were 61.4 euros. The percentage ratio between the other costs and the waste costs was 4.4%.

The mixed waste costs for 2019 (last completed year) were 5,866 euros , plus bin rental for 125 euros. Other costs were 186 euros. Total waste collected (not weighted): 22,680 kilograms of mixed household waste. Costs per apartment were 93.6 euros. Costs per tenant were 52.3 euros. The percentage ratio between the other costs and the waste costs was 3.1%.

Kalastajanmäki 3 (8 mixed waste trash cans)

Total waste collected (not weighted): 15,984 kilograms of mixed household waste. This cost 4,427 euros and 208 euros in bin rentals. Other costs were 69 euros. Costs per apartment were 68.2 euros. Costs per tenant were 36.2 euros. The percentage ratio between the other costs and the waste costs was 1.48%.

Total waste collected (not weighted): 15,984 kilograms of mixed household waste. This cost 3,805 euros and 177 euros in bin rentals. Other costs were 21 euros. Costs per apartment were 58 euros. Costs per tenant were 30.8 euros. The percentage ratio between the other costs and the waste costs was 0.5%.

Kaskimaa 4 (5 mixed waste trash cans)

The mixed waste costs for 2018 were 5,632 euros , plus bin rental for 125 euros. Other costs were 150 euros. A 25% decrease would lower the costs in total by 1,439.25 euros. Costs per apartment were 109.7 euros. Costs per tenant were 61.4 euros. The percentage ratio between the other costs and the waste costs was 4.4%.

The mixed waste costs for 2019 (last completed year) were 5,266 euros , plus bin rental for 110 euros. Other costs were 20 euros. A 25% decrease would lower the costs in total by 1,439.25 euros. Costs per apartment were 99.9 euros. Costs per tenant were 40.3 euros. The percentage ratio between the other costs and the waste costs was 0.4%.

Leppäviita 1 (4 mixed waste trash cans)

Average fill rate of the trash bins was 50.6%. Not taking the end of the month visit into account brings the average to 41.25%. The costs were 4,574 euros and bin rental for 100 euros. Other costs were 37 euros. Costs per apartment were 109.6 euros. Costs per tenant were 54.8 euros. The percentage ratio between the other costs and the waste costs was 0.7%.

Average fill rate of the trash bins was 50.6%. Not taking the end of the month visit into account brings the average to 41.25%. The costs were 4,199 euros and bin rental for 88 euros. Other costs were 34 euros. Costs per apartment were 100.5 euros. Costs per

tenant were 50.2 euros. The percentage ratio between the other costs and the waste costs was 0.8%.

Norkkokuja 3 and 4

The mixed waste costs for 2018 were 4,582 euros, plus bin rental for 219 euros. Other costs were 564 euros. Costs per apartment were 87.9 euros. Costs per tenant were 36 euros. The percentage ratio between the other costs and the waste costs was 11.7%.

The mixed waste costs for 2019 (last completed year) were 3,802 euros , plus bin rental for 171 euros. Other costs were 290 euros. Costs per apartment were 69.9 euros. Costs per tenant were 28.6 euros. The percentage ratio between the other costs and the waste costs was 7.3%.

Ryytimaantie 2

The mixed waste costs for 2018 were 1,588 euros , plus bin rental for 75 euros. Other costs were 6 euros. Costs per apartment were 151.7 euros. Costs per tenant were 53.8 euros. The percentage ratio between the other costs and the waste costs was 0.3%.

The mixed waste costs for 2019 (last completed year) were 1,488 euros , plus bin rental for 66 euros. Other costs were 4 euros. Costs per apartment were 141.6 euros. Costs per tenant were 50.3 euros. The percentage ratio between the other costs and the waste costs was 0.3%.

Puunhaltijankuja 1-3

The mixed waste costs for 2018 were 6,034 euros , plus bin rental for 134 euros. Other costs were 409 euros. Costs per apartment were 91.3 euros. Costs per tenant were 50.2 euros. The percentage ratio between the other costs and the waste costs was 6.6%.

The mixed waste costs for 2019 were 4,400 euros , plus bin rental for 93 euros. Other costs were 228 euros. Costs per apartment were 65.6 euros. Costs per tenant were 36 euros. The percentage ratio between the other costs and the waste costs was 5.0%.

Ränkitie 1-3

The mixed waste costs for 2018 were 11,982 euros , plus bin rental for 266 euros. Other costs were 174 euros. Costs per apartment were 197.2 euros. Costs per tenant were 83.4 euros. The percentage ratio between the other costs and the waste costs was 1.4%.

The mixed waste costs for 2019 (last completed year) were 10,521 euros , plus bin rental for 220 euros. Other costs were 218 euros. Costs per apartment were 174 euros. Costs per tenant were 73.5 euros. The percentage ratio between the other costs and the waste costs was 2.0%.

Sorakuja 5

The mixed waste costs for 2018 were 3,911 euros , plus bin rental for 85 euros. Other costs were 197 euros. Costs per apartment were 76.2 euros. Costs per tenant were 51.8 euros. The percentage ratio between the other costs and the waste costs was 4.9%.

The mixed waste costs for 2019 (last completed year) were 3,186 euros , plus bin rental for 66 euros. Other costs were 462 euros. Costs per apartment were 67.5 euros. Costs per tenant were 45.9 euros. The percentage ratio between the other costs and the waste costs was 14.2%.

Viittakorpi 2

The mixed waste costs for 2018 were 6,870 euros , plus bin rental for 149 euros. Other costs were 44 euros. Costs per apartment were 181.1 euros. Costs per tenant were 72.8 euros. The percentage ratio between the other costs and the waste costs was 0.6%.

The mixed waste costs for 2019 (last completed year) were 6,440 euros , plus bin rental for 133 euros. Other costs were 50 euros. Costs per apartment were 169.9 euros. Costs per tenant were 68.3 euros. The percentage ratio between the other costs and the waste costs was 0.8%.

8.2 Comparison to other cities

All the locations in this study were located in either Helsinki, Vantaa, or Espoo. To have something to compare these numbers with, some data was gathered from the cities of Tampere, Turku, Kuopio, and Kotka. The sample size and scope of the provided data were quite small to make any drastic assumptions. The thing that was gained was the “waste costs per apartment” numbers of a few locations per city. This is not particularly useful because there were no specifications if the houses were apartment houses or terraced houses. Still, the following graph was the result of this data.

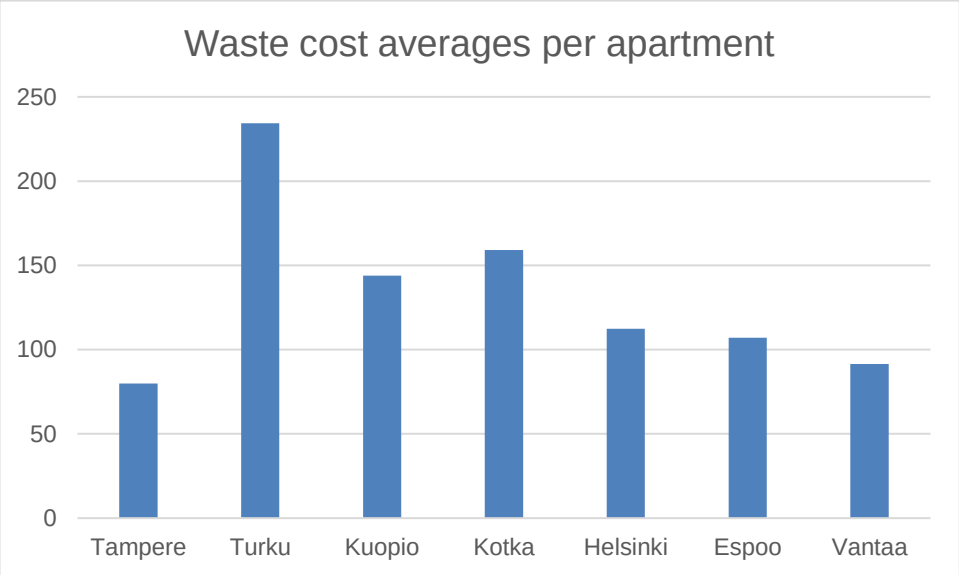

Image 19. Waste cost averages per apartment

As can be seen from Image 19, the costs are quite uniform across the board, with Turku being the sole exception. The one thing that is noteworthy, is that the cities that had the locations chosen for this study all had quite low waste costs per apartment. It should be kept in mind though, that there is no data available to show what waste collection method the other apartments had. They could be all using the deep collection method in Turku for example, thus distorting the comparison. As such, not too much attention should be paid to this part of the study.

8.3 Summary

If we take the averages of the 4th visit, being the visit with the highest average fill rates, and use that as a basis for the optimization, terraced houses have 32.1 percent overcapacity and apartment houses have 13.6 percent overcapacity. If we remove this overcapacity from the total waste costs, savings of 7,876 euros and 3,699 euros could be achieved, respectively. In reality this isn't totally fair and reasonable because it is not possible for example to remove 0.5 waste bins from a location, but this in theory proves that a lot of optimization could be done, and a lot of costs could be saved. What must be kept in mind is that this is merely a scratch to the surface of waste optimization. This was a study done on just 10 locations, and yet a sizable amount of money was saved. The same problem was observed in all locations, so presumably this is quite common, and the learnings from this study can be taken advantage of elsewhere too.

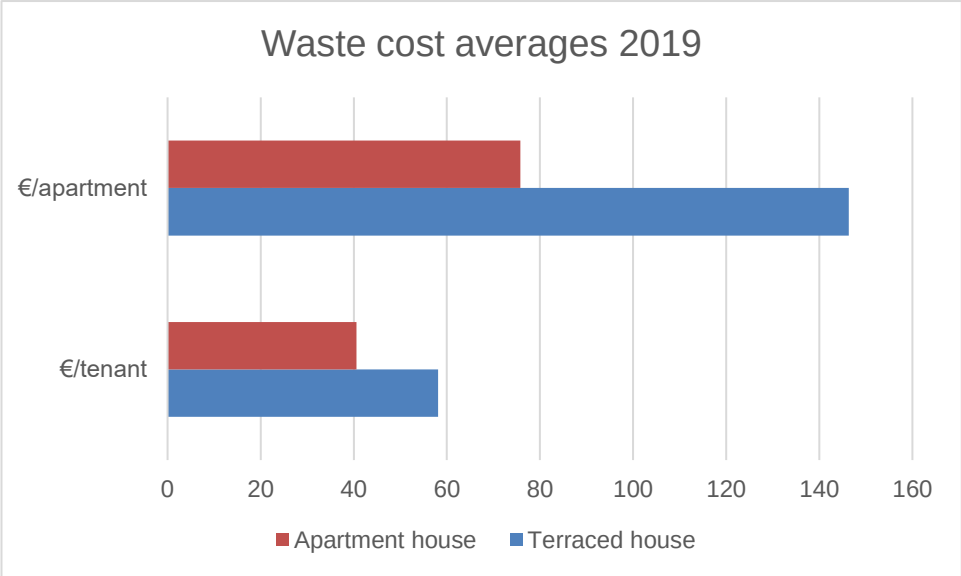

Image 20. Waste cost averages 2019.

As can been from image 20, the difference in waste cost averages between apartment houses and terraced houses are quite big. Especially the difference per apartment, being almost double in terraced houses than it is in apartment houses. This can be somewhat explained with larger numbers of tenants per apartment in terraced apartments, but not completely. Per tenant the difference goes down, but there is still a difference which proves that the increase in tenants per apartment is not the sole reason for this increase.

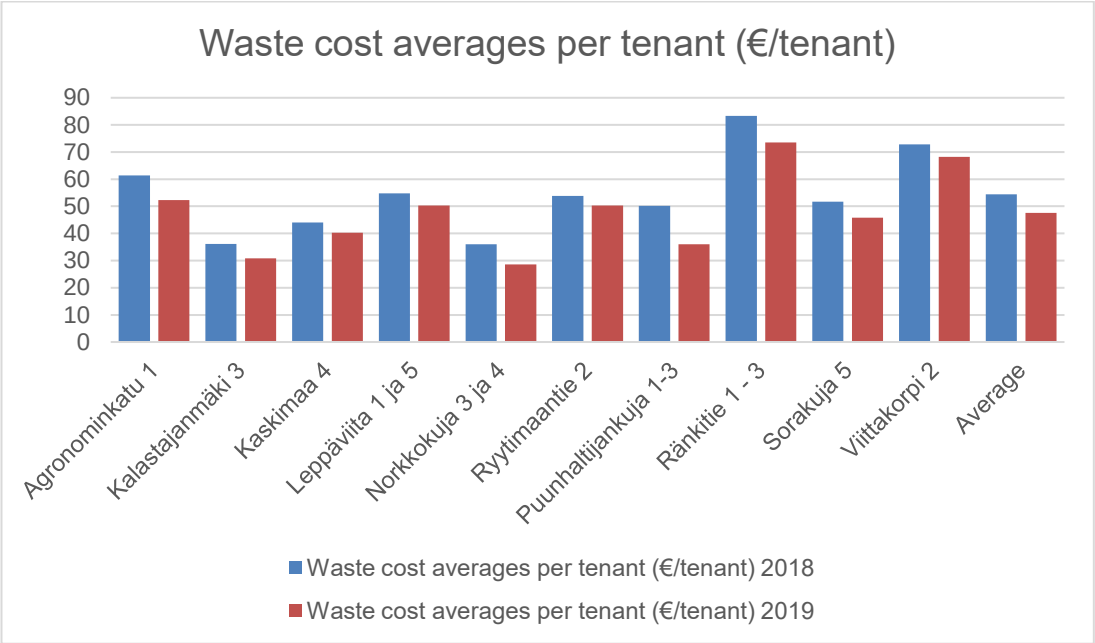

Image 21. Waste cost averages per tenant.

As can be seen in image 21, there is a trend of decreasing waste costs. This trend can be observed on every metric used in this study.

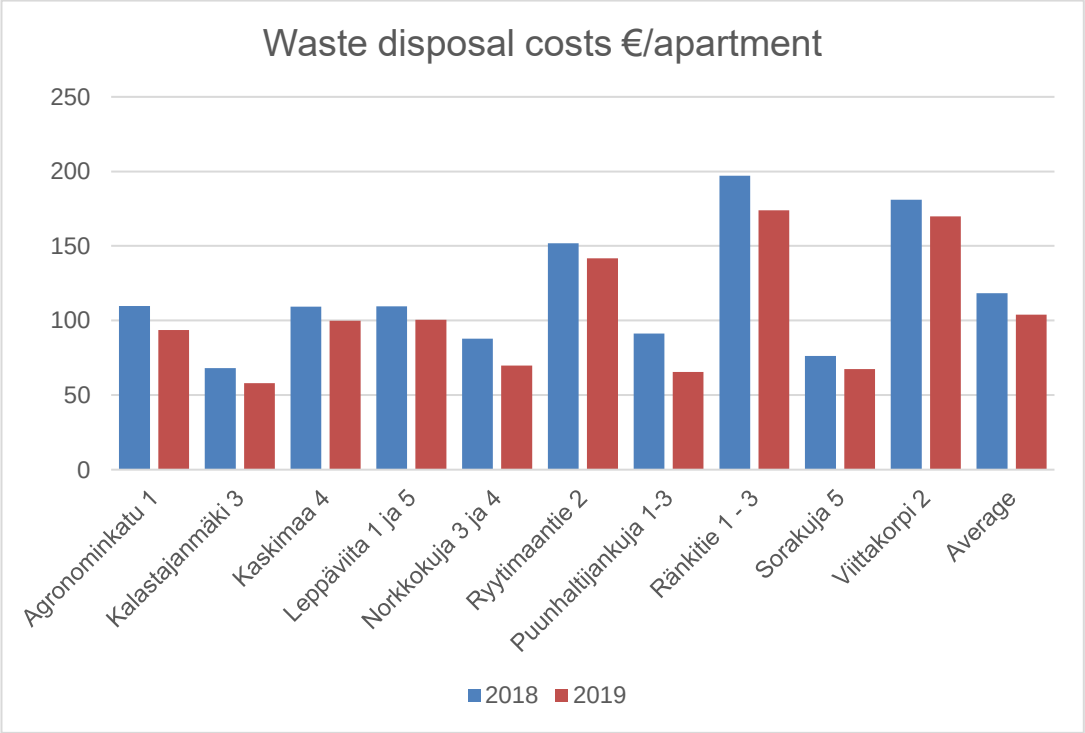

Image 22. Waste disposal costs per apartment.

As can be seen in image 22, waste costs in general have gone down in every location taken as a data collection point for this study. This can be attributed to several things, for example the addition of plastic collection containers, which are cheaper than mixed waste containers for the apartments.

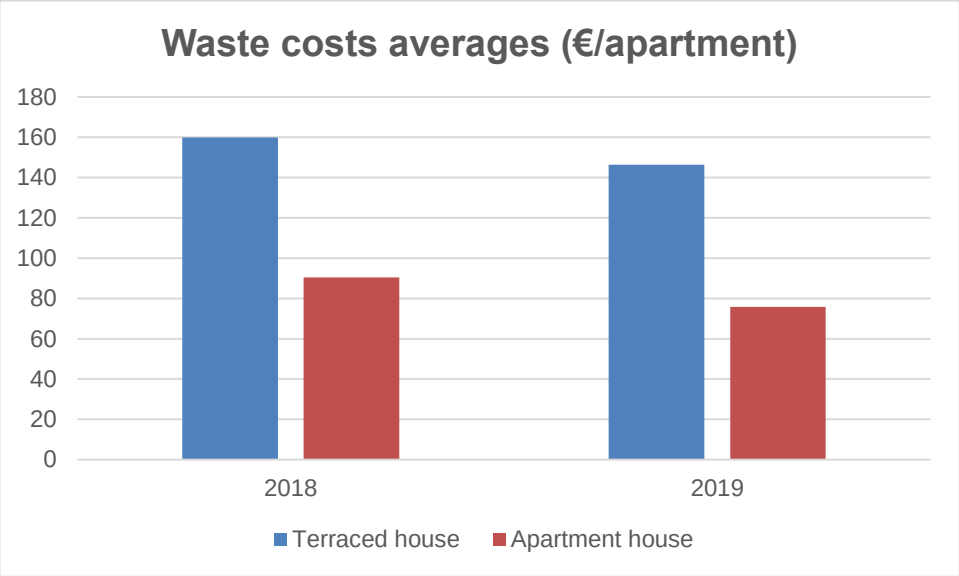

Image 23. Waste costs averages.

As can be seen in image 23, the trend that was indicated in image 22, of waste disposal costs decline per apartment, the averages for apartment houses and terraced houses have also declined from 2018 to 2019. This is a good indication of things to come, and it clearly shows that even minor changes in waste management result in cost savings, and thus optimization.

9 Conclusion

Generalizations can be made from the data. The data indicates that at the end of the month, the fill rates are the largest. Outside of this time period, the waste disposal facilities are not optimally utilized.

Apartment houses generate more waste, possibly because they tend to have a higher chance of people moving out.

The method of choosing the waste disposal method is a complex issue. On the other hand, as said previously, the tube method decreases the amount of traffic in the area, and the dump trucks will not be driving around at breakneck speeds through the tiny streets, generating a hazard for small children. This also means less pollution and an increase in air quality, with the removal of heavy diesel engines from the narrow district streets.

Certain Key Performance Indicators can be derived from the data collected, for a normal apartment house with the x number of tenants must not exceed x number of euros paid for waste disposal, on average. This number must be fair and backed by data. When cross referencing with data collected from other cities, the KPIs can be enhanced to benefit the analyzing of waste disposal costs across the country and open up possibilities of finding out what other cities are doing better.

What can be deduced from the data is that terraced houses have larger waste disposal costs than all the other types of buildings. The averages for the terraced houses in 2018 were 159.8 euros, compared to the apartment house averages being only 90.5 euros. This is a marked increase of 76%. In 2019 these numbers amounted to 146.3 euros and 75.9 euros, respectively. These are also the apartment types with less change in the tenants, meaning less people moving out at the end of the month.

Then again, the average fill rates of the terraced houses are lower than the corresponding ones of apartment houses. The averages for apartment houses being 57.6% and for terraced 40.3%. A 17.3% decrease would mean that the average price of waste disposal would go down to being 46% higher than in apartment houses.

Ratio between waste costs and the other costs, which include trash that was on the floor of the waste disposal location, furniture, trash that was in bags on the floor, textiles and loose waste, packaging waste, renovation waste, and garden waste, were much higher in some places than in some places. For example, in 2018, at Agronominkatu 1 (4.4%), Kaskimaa 4 (2.6%), Norkkokuja 3 and 4 (11.7%), Puunhaltijankuja 1-3 (6.6%), and Sorakuja 5 (4.9%). It is worth noting that 2 of these are so-called Ekokompassi-locations, which have an increased amount of effort to raise recycling awareness. Norkkokuja is by far the worst example of this behavior, with Norkkokuja 3 having 388 euros in loose waste-charges on its record. The worst contenders were all apartment houses. Most of the terraced house locations fared quite well.

In 2019 the worst contenders were once again Agronominkatu 1 (3.1%), Norkkokuja 3 and 4 (7.3%), Puunhaltijankuja 1-3 (5.1%), and Sorakuja 5 (14.2%). Kaskimaa 4 had fared much better this time around, only having a ratio of 0,5% which is a marked decrease in other waste costs. Of note, once again is that 2 of these are so-called Ekokompassi-locations, which have an increased amount of effort to raise recycling awareness. Sorakuja 5 is by far the worst example of this behavior this time around, having 462 euros in loose waste-charges on its record. The worst contenders were all apartment houses. Most of the terraced house locations fared quite well.

In conclusion the cheapest method was either the deep collection method or regular bins. The regular bins were expensive in some cases though, with the automatic waste collection method being very expensive.

10 Recommended course of action

In order to improve waste management in rental properties, the following recommendations are given. Adapting multiple of the following recommendations could be beneficial and amount to cost savings.

The first recommendation is deducing key performance indicators, which could be utilized by the landlords to follow the waste disposing habits of the tenants, and in turn rectify them if need be. Differing KPIs could be set as targets for differing types of houses, such as terraced house and apartment houses. These KPIs could act as guidelines to help achieve better efficiency, and to monitor how things have progressed. A certain KPI could be for example the costs per tenants or per apartment.

The second recommendation is enhancing recycling awareness within tenants. Recycling is beneficial to the environment and cost effective.

The third recommendation is graduated moving days. This would make sure that not all waste generated by inhabitants moving away, gets disposed of at the same time. This would help avoid and decrease the fill rate peaks as seen in the data.

The fourth recommendation is skip for furniture. Another problem generated by the month changing and tenants moving is the furniture. People have no convenient way to dispose of it, so they will eventually merely dump it next to the waste disposal location. This costs always extra and is very expensive. Taking it to a landfill is too much trouble for the common man who is reluctant to do more than it takes. Easy access and a way to dispose of the furniture is an excellent incentive to increase the likelihood of the furniture ending at the right waste disposal facility.

The fifth recommendation is recycling competition for tenants could be an idea to increase the motivation that tenants have for recycling. Competition often works wonders in generating awareness through the competitive nature of people. Prizes could be anything really, if there is an incentive to do something differently. This could work, but then again human nature is fickle and resistant to change.

The sixth recommendation, rewarding tenants for recycling goes well with the previous suggestion. Prize could be lower rent, or a leisurely activity organized for the whole apartment complex. This can be done the other way too, with the landlord rewarded when meeting targets set by the apartment owner company.

The seventh recommendation is monitoring of fill rates in new rental property locations, after the move-in period when situation has normalized. This would improve the accuracy of predictions. Locations with less apartments have less people moving in and out every month, and this has to be taken into consideration.

The eight recommendation is taking random samples and spot checks at rental properties to deduce the accuracy of the optimization. This must be done to increase the reliability of the optimization, and people's trust in the numbers generated by it.

The ninth recommendation is the amount of waste disposal storage has to be adapted to normal conditions, and the peaks can be nullified using, for example a circulating actor (cheaper than ordering a trash skip), who collects all "overfill" at the end of the month from the locations that have a lot of moving tenants. This also offsets for example the holiday chaos at the waste disposal rooms. Locations must be surveyed to identify the ones that have a lot of variability among the tenants. The amount of people leaving must be considered when tracking the fill rates and increasing of waste disposal facilities usage.

The tenth recommendation is that more data must be gathered, especially regarding other classes of waste. Influence on general fill rates must be considered.

The eleventh recommendation is that in subsequent investigations of fill rates with the intent of optimizing the costs, more data must be gathered to accurately predict the continuity and seasonal fluctuations in waste generation.

The twelfth recommendation is that inclusion and effect of other waste types and their subsequent fill rates should also be considered, as in if the other bins are full of mixed waste if the intended locations are already full.

In conclusion, a lot can be done to optimize waste management in rental properties. Different key performance indicators and metrics could be generated from the data collected in this empirical study. The limited number of locations and visits to them, means that additional data could prove to be very useful when coming up with these new indicators. Nonetheless the goals of the study were reached, and the data solidifies the hypothesis, that rental properties waste management is negatively affected by lack of optimization. The waste disposal locations are often underused, except at the end of the month, when they are overused. Terraced apartments generate more waste per inhabitant and per apartment than apartment buildings, and the waste costs associated with terraced houses are as a result of this, higher. The terraced houses have a lower amount of new people moving in year around than apartment houses, because of the lower number of apartments. This is prime opportunity to better educate the inhabitants in terraced houses to recycle better, because the terraced houses have more room for improvement with their higher waste generation, when measured per inhabitant. Likewise, the terraced houses have the most room for optimization, as was shows in the empirical section of this study. Apartment buildings, likewise, benefit from the optimization. Often the waste rooms were dirty because of filled waste bins, this could be avoided with better optimization.

All these actions rely entirely on the companies managing the rental properties, and their willingness to impactfully enact changes. It is made easier for them to enact environmentally conscious decisions, because waste optimization can generate quite large savings. These waste management optimizations benefit both the companies managing the buildings, and the inhabitants of the rental properties as well. Finally, the environment also benefits from these actions, by a greater number of municipal waste getting recycled into new materials.

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