Exploratory Study of Waste Generation and Waste Minimization in Sweden

Dina Kuslyaykina

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Dina Kuslyaykina

Supervisor: Prof. Lars Rydén
Evaluator: Prof. Hans Liljenström
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Abstract: The current thesis presents an exploratory study on municipal solid waste generation and minimization in Sweden, with a focus on their connection to basic socio-economic parameters. The fundamental goal of the study is to investigate into correlations and interdependencies between waste generation, waste minimization and basic socio-economic characteristics on municipal level, and to search for models for explanation of waste management parameters through socio-economic factors. Theoretical background involves reasoning on the role of municipal waste management in sustainable development, and extensive analysis of framework, legislation and organization of municipal solid waste management in Sweden. Practical part presents correlation analysis of data, which proved that socio-economic parameters do not explain differences in waste management performance of Swedish municipalities; however they are closely connected to differences between municipalities in aspect of presence of waste-related data.

Keywords: Sustainable Development, waste management, waste hierarchy, waste generation, waste minimization, municipal solid waste in Sweden

Dina Kuslyaykina, Department of Earth Sciences, Uppsala University, Villavägen 16, SE- 752 36 Uppsala, Sweden
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Summary: Waste management is an important field to study within sustainability science, as waste presents a resource and should be handled properly both for environmental safety and economic benefits. The current thesis is devoted to municipal solid waste management in Sweden, and more specifically, to relations between waste generation, waste minimization and socio-economic parameters. Exploratory nature of the current thesis determined its goal as an investigation into possible dependencies and correlations between waste generation, waste minimization steps, and basic socio-economic characteristics of a municipality, in order to assess the possibility to explain some of these parameters through others. Understanding of the relations between waste management parameters and socio-economic characteristics might provide new insights into local waste management solutions.

Theoretical part of the study is predominantly devoted to analysis of framework, legislation and organization of municipal solid waste management system in Sweden. Laws and regulations (including ones laid down by the European Union), main actors, governmental bodies, and the state of the art in the Swedish waste management are described to provide a solid basis for introducing waste minimization steps, grounded on waste hierarchy. For developing ideas about possible socio-economic factors influencing waste generation and management, previous research overview was performed as a background for the study.

Practical part of the research was based on statistical analysis of basic socio-economic parameters of municipalities (area, population size and density, mean age and median income of inhabitants) and the data on their waste management performance (amounts of waste per capita at each of the stages of waste minimization). Due to high share of missing values in the database, the analysis of missing data was especially detailed and productive: interdependencies were discovered between some characteristics of municipalities and the integrity of data they submit to the database. The general tendency for differences between municipalities depending on the availability of their data in the database, is that the municipalities which have missing values, also have lower average population density, bigger area, smaller median income and tend to send more waste to biological treatment than municipalities with valid data. The results of the correlation analysis proved that socio-economic parameters do not explain differences in waste management performance of municipalities; however they are closely connected to differences between municipalities in aspect of waste-related data availability. This result of a practical investigation within the present thesis is important as it sheds light on the municipalities which created a high share of missing data. Such result also opens prospects for future research in the field, which calls for softer qualitative methods, as the differences in waste management performance of municipalities should be explained by other factors than socio-economic, and these local factors present an interesting subject for further studies.

Keywords: Sustainable Development, waste management, waste hierarchy, waste generation, waste minimization, municipal solid waste in Sweden

Dina Kuslyaykina, Department of Earth Sciences, Uppsala University, Villavägen 16, SE- 752 36 Uppsala, Sweden
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1. INTRODUCTION

The concept of waste connects humans with their living environment: waste means useless materials, which are not required in some system (of household, production, or consumption) and are placed, or supposed to be placed, outside of it. Strict definitions of waste are presented further in the paper, but the core of the notion of waste at the common sense level is the idea of objects or substances, that are considered useless by some subject (waste holder) and are discarded from the system under consideration. Such approach requires systems thinking to understand that every system is a part of a bigger and more complex system, and therefore waste is not disappearing from the bigger system, the environment. This fact simultaneously relates to the problem of deep interconnectedness between environmental, social and economic realms of life. Waste, as a by-product of social and economic activity, which affects the environment, presents an interesting phenomenon to study within the field of sustainability science.

Moreover, waste is also involved in social relations, which is reflected in an idiom “one man’s trash is another man’s treasure”. This is justified by the fact that waste, being a useless object or substance within waste holder’s system, actually presents a resource, which might present value and still be used in some other system. Not only household belongings might be “given a second life”, but also resources from waste, such as materials or energy, which can be reused or recovered to enter a new life cycle.

The problem of waste generation is one of the key environmental problems of modernity, being intertwined with and also contributing to other environmental challenges, such as, for example, greenhouse gas emission, land use, depletion of non-renewable resources and freshwater contamination.

According to Eurostat (Eurostat, n.d.), the amount of waste produced in 27 member states of the European Union (hereafter – the EU) in 2010 was equal to 252095 thousand tonnes. The figures have been even larger previously, and also a significant share of waste generated in Europe is still landfilled. In fact, large amounts of waste and negative consequences of its deposition on landfills first became a problem in the 1970s in Germany, so the country had to “restrict the dumping of waste in landfills … and to introduce rules and taxes to reduce waste” (Zbicinski et al. 2007, p.157). Other European countries followed the example, as it was both environmentally and economically costly to deposit all the waste on landfills, where it prevents land from alternative use and pollutes the environment, for example via leakage into groundwater.

Waste, though often perceived as solid substances, can have other possible forms, or states of matter (Zbicinski et al. 2007), including liquid waste (such as sewage water) and gaseous waste (for instance, CO₂ and other greenhouse gases – often referred as “molecular waste”). Within the scope of the current paper, only municipal solid waste (hereafter - MSW) is considered, several subtypes of which are also omitted according to delimitations presented further. This scope also leaves behind other types of solid waste than municipal: industrial, mining and construction waste, which is altogether usually called industrial waste, as opposed to municipal waste (mainly consisting of everyday life refuse). Being aware about the importance of reduction and recycling of these types of waste, regardless to their physical form, and fully sharing the aim of cleaner production, the author nonetheless leaves these types of waste out of consideration.
Fig. 1 Types of waste and the focus of the current paper

**solid:**
- municipal solid waste, includes “wastes produced by residential, commercial and public services sectors that are collected by local authorities for treatment and/or disposal in a central location”
- industrial solid waste, includes industrial, mining and construction wastes

**liquid:** waste in liquid form, such as wastewater

**gaseous:** waste in molecular form, such as CO₂


Sweden has developed an advanced approach to waste management based on waste minimization on all the stages of it, but of course the amounts of waste generated, treated and sent to deposition differ in Swedish municipalities. Understanding the reasons behind the efficiency of waste minimization and the amount of waste generated in different municipalities might provide a better insight into necessary local adjustments of waste management policies and contribute to reduction of the amounts of waste to deposit. Even such a broad core idea of approaching waste management, as famous 4R formula (International Institute for Sustainable Development 2012), might be adapted and customized for local management, given the information about which of the Rs – reducing the amounts of waste generated, reusing things, recycling of materials or waste recovery into new materials or energy sources – has a bigger effect on reduction of waste output in the end in every particular economic and geographic area.

Which of the stages of waste management is more important for waste minimization? Which of the Rs – reducing the amount of produced waste, recycling materials or waste recovery – has a bigger effect on reduction of waste output and prevents more waste from reaching the last stage of waste management and being landfilled (or deposited in any other way)? Are social and economic characteristics playing a more important role in waste generation and minimization?

The current thesis is devoted to investigation of waste generation and minimization in Sweden, as well as to priorities of national waste management, and presents a combination of theoretical research into framework and organization of waste management in Sweden, and practical exploratory part with statistical analysis of parameters, which potentially affect waste generation and minimization in Swedish municipalities, in order to find out the most important and influential of them.
1.1. Relevance of the Topic

The reasons for the topic of waste generation and waste minimization in Sweden to be relevant and vital are multiple. First, the global framework for investigating into the topic of waste minimization is grounded on the need of the global community to address the problem of increasing waste amounts. This problem is connected both with growing global population and with developing national economies. Second, narrowing down the regional scope to Sweden’s waste management corresponds to Swedish aspirations for even more effective system of managing waste flow, less waste deposition and minimization of harmful effects of waste management to the environment and human health. Knowing more about actual contributions of waste minimization steps to overall waste minimization in every municipality in Sweden might provide local authorities with a basis for new solutions and decisions. Also, the information on characteristics which influence waste generation might help to develop measures to reduce waste amounts.

From the standpoint of sustainable development, researching into waste generation and minimization belongs to the field of studying the features of influence of social, economic and technological factors on environment and use of natural resources. One of subchapters further is devoted to discussion of waste from the viewpoint of sustainability science in more detail.

Moreover, if the current exploratory study finds new factors which explain differences between municipalities in the sphere of waste management, then the results can be applied to other cases of waste management systems comparison, for example, to comparison of waste management systems in the EU member states. The result of future research into the topic might provide an idea about effective and necessary local waste minimization measures.

1.2. Research Problem

As already mentioned above, the real-life precondition to the research problem is the fact that waste minimization efficiency and waste generation vary in different Swedish municipalities. Through analysis of the data about waste quantities and some socio-economic characteristics of the municipalities, the current research intends to consider and evaluate the dependencies between waste generation, waste minimization steps and socio-economic parameters, which might explain the abovementioned differences, as well as provide information on effectiveness of waste management steps for waste minimization.

It is important to emphasize, that this paper is not questioning the acknowledged waste hierarchy and the 4R formula of waste management. In full consent with thermodynamics, the current research also shares the vision of prevention being the most favourable measure to reduce waste output, being followed by reusing, recycling, and then recovery. Every stage of waste management requires effort, resources and energy, and the higher stage of waste management becomes final for waste, the less energy is needed to carry out waste management procedure. In other words, it is a lot cheaper to prevent or reuse, than to recycle or to perform recovery. However, the hierarchy is not always a rigid rule (Zbicinski et al. 2007, p.159), but more of a recommendation, so it is allowed to reconsider the importance of steps for each and every community: there is “flexibility required when selecting the most environmentally effective and economically efficient method of waste management for a specific geography/location” (Zbicinski et al. 2007, p.159). So, besides general exploration of interdependencies of waste generation, minimization and socio-economic characteristics, the
current study, using the case of Sweden and Swedish municipalities, is aimed to investigate into contributions of waste minimization steps of waste management into overall result of waste reduction.

1.3. GOALS AND OBJECTIVES

The goals of the current exploratory research are to describe the dependencies between waste generation, waste minimization steps, and socio-economic characteristics of a municipality, and to assess the possibility to explain some of these parameters through other by building possible models reflecting the structure of these dependencies.

To achieve these goals, several objectives need to be met:

1. To describe current system of waste management in Sweden, with the focus on priorities of waste management, waste minimization measures and quantities of waste produced;
2. To introduce quantitative variables representing waste generation, waste minimization steps and socio-economic characteristics of a municipality;
3. To collect statistical data about those parameters;
4. To perform analysis of the dataset;
5. To interpret the results of the analysis;
6. To draw conclusions about the interdependencies between these variables, and causal structure, if any is discovered;
7. To propose directions for further research on the topic.

1.4. OBJECT AND SUBJECT OF THE RESEARCH

The object of the research, or the actual part of reality under consideration, is Swedish system of waste management, including its legal, organizational, administrative, and substantial aspects. The reasoning and analysis of the current paper are based on understanding the general flow of waste management in Sweden. The subject of the research, or the substantial side of object under consideration, is “waste minimization and priorities of waste management”.

1.5. SOURCES OF INFORMATION

The knowledge to support the research lies mainly within publications on waste management, previous studies on waste generation factors, European and Swedish legislation on waste, and publications of Swedish Environmental Protection Agency – Naturvårdsverket.

The empirical database for the analysis is provided by Avfall Sverige AB – Swedish Waste Management, which is a branch organization, coordinating the work of actors involved in waste management and recycling industry in Sweden. The mission of Avfall Sverige is “development of environmentally sound, sustainable waste management based on a clear social responsibility” (Avfall Sverige AB, 2010, p.2). Another source of data for empirical research is Statistiska Centralbyrån, the Swedish Statistics, as they provide regional statistics about the main demographic, social and economic characteristics which presumably affect waste generation and waste management and would be therefore incorporated in the analysis.
1.6. FOCUS, DELIMITATIONS AND CONSTRAINTS

The current research has a range of certain delimitations, connected with both substantial and methodological aspects.

First, only municipal solid waste (MSW) is considered within the scope of the current paper. According to the definition of the European Union, municipal solid waste includes “waste from households, as well as other waste, which, because of its nature or composition, is similar to waste from households” (Eionet 2012). This definition originated from Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, and was later complemented by an EU definition of “mixed municipal solid waste”, which emphasizes that MSW is “mixed” because it includes waste from households as well as commercial, industrial and institutional waste, which because of its nature and composition is similar to waste from households – for example, waste from small businesses, office buildings, public institutions (Eionet 2012). According to this definition, besides everyday refuse, MSW also includes bulky waste, park and garden waste (both public and private), waste from street cleaning services, fractions collected separately, waste electrical and electronic equipment (hereafter - WEEE), and hazardous waste. An important idea about the definition of municipal solid waste is that it means waste, which is collected by, or on behalf of municipality, and at municipal level. Also, it is important to remember what is excluded from MSW, and an illustration is available above (see Fig. 1) – MSW does not incorporate industrial solid waste, and also sewage.

Second, within the definition of MSW, the current paper also excludes from consideration WEEE, hazardous, toxic and medical waste. These types of waste require special collection and treatment, and therefore deserve independent investigation into waste management approaches, legislation, generation factors and minimization strategies. The legislation regarding these types of waste is only briefly touched upon, and the correspondent data is not included in the analysis.

Third, within the abovementioned 4R formula of reduce, reuse, recycle and recovery, only three R’s are going to be incorporated in the scope of the paper, as at the municipal level there is hardly any possibility to measure reusing ratio in each municipality, as this parameter requires a lot of assumptions and estimations, and a detailed study on household level instead of municipal level. Therefore, only reducing, recycling and recovery would be incorporated into analysis. Moreover, the phase of “reduction” is of course inverted (as it is too complex to assess how much waste was not produced), and presented as waste generation. The only difference would be positive influence of reducing waste onto overall waste minimization (minimization of landfilled waste), which is substituted by negative influence of waste generation on waste minimization. Also, waste generation is a concept in itself, as further in the paper the factors which affect waste generation (and can be therefore interpreted as spheres to work with waste reduction), would be considered. Waste minimization is measured as an opposite concept of landfilled waste, as waste minimization is a process with an end goal of minimizing the amount of waste to deposit.

The following illustration sheds light on the structure of waste minimization and waste generation, as they are presented within the current paper:
The choice of socio-economic parameters is to be explained further in the paper, and the aim of the current research is transformed onto Fig. 2 is to find dependencies and possible structure connecting elements on its left side.

Methodological constraints are described in the part devoted to practical analysis of data, as they are grounded on mathematical assumptions under methods used, and also the restrictions connected with the data characteristics and availability.
2. WASTE AND SUSTAINABLE DEVELOPMENT

The current chapter presents an outline of main issues, which connect the concept of waste to sustainable development and sustainability science.

Definitions of waste slightly differentiate between sources. For example, the Organisation for Economic Co-operation and Development (hereafter – the OECD) and the United Nations (hereafter – the UN) provide the following definition: “Waste refers to materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities” (United Nations, 1997)

The EU, within the Framework Directive on Waste, defines waste as “any substance or object which the holder discards or intends or is required to discard”. Within the current paper, the EU definition is employed. The definition of MSW, which presents the object of the current research, has been already given above in subchapter 1.6.

Waste management is important for proper functioning of society, both environmentally and economically. Smart strategy for waste management can contribute to saving resources and energy, and therefore to allocating them for better purposes than letting them simply be wasted. The last important definition to provide is the definition of waste management itself, which is also provided by the EU Waste Framework Directive.

“Waste management means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker” (The EU Waste Framework Directive, Article 2) Other important definitions can be found in Appendix.

2.1. THE CONCEPT OF WASTE AND ITS EVOLUTION

Waste, as a by-product of people’s economic and household activity, has existed as long as the humanity existed. The ties between waste and civilization development seem even closer, considering that a lot of knowledge that archaeologists and historians have nowadays originated from excavating garbage, demolished houses or other remains of our predecessors’ estate and belongings (Barbalace 2003). However attitude towards waste, its amount, composition and the way of taking care of it differs a lot both regionally and historically. First, before rapid growth of population the amounts of waste generated globally were significantly lower than contemporary amounts of waste generation. Second, before scientific and industrial development most of the waste produced was biodegradable. Also, before the industrialization, practices of taking care of waste were to a larger extent based on using the value of waste, as “waste was taken care of as a resource” (Zbicinski et al. 2007, p.158). Landfills and municipal solid waste management (hereafter – MSWM) in the modern sense developed after the process of urbanization reached its peak. “In pre-industrial society discarded material was not thrown away but used for some purpose. Products were repaired, or parts of it were used in new products or for new purposes; organic material was sent back to cultivated land, and burnable material was used for heating” (Zbicinski et al. 2007, p.157).
Responsibilities of municipal units (cities or municipalities) to take care of waste initially became the result of rapid urbanization and industrialization, and the necessity to protect public health about a century ago (Product Policy Institute 2012). However, the composition of urban waste was different from the modern composition. Waste in the cities was almost reduced to coal ash and food leftovers, with a very small share of manufactured goods. Currently, “throw-away products and packaging” (according to Product Policy Institute 2012) account for a much bigger share of waste, just because of consumption patterns of the modern society. The inevitable result of it is increasing share of so-called “product waste” (as opposed to bio-waste and inorganic waste), coming from high consumption levels in Europe and the USA (Spiegelman and Sheehan 2005). During the past century the relation to product waste has changed: product waste as we perceive it now is a relatively new concept, as previously, with lower rates of consumption, people used to repair more and maintain old products to extend their life cycle.

When the composition of waste started to diversify and everyday public waste grew in amount and started to include more hazardous and toxic substances, landfills and open dumps were not a satisfying solution anymore. Overloaded, leaking into groundwater and emitting CO₂, landfills started to be perceived as signs of MSWM crisis, and required new solutions for waste minimization and waste treatment. The period of this crisis differs for different countries, but according to Spiegelman and Sheehan (2005) in the USA and Europe it might be related to 1960s, 1970s and 1980s. For example, “in Germany, Denmark and the Netherlands in response to the pressure of environmental groups, a policy process began in the early 70s, which aimed at establishing the prevention ladder” (Hafkamp 2002, p.17). Therefore new approaches towards waste management started to emerge as a measure to reduce the amount of waste landfilled, along with new regulations to reduce negative consequences of hazardous waste disposal. Communities started to practice recycling of waste again. The area of searching for MSWM solutions switched from collection and deposition to prevention and recycling. The process of return of waste as a resource has started then.

So, contemporary waste management in Europe is turning back to the idea of waste being a useful resource. The idea of extracting the resources back out of waste is now returning into waste management, and is incorporated into waste hierarchy: recycling saves not only material, but also energy needed for production, and in case recycling is not applicable to some types of materials or parts of objects, then energy recovery is performed to at least use the available energy. Biological treatment of organic waste is performed to extract useful energy or nutrients. Recycling, recovery and biological treatment are both environmentally-friendly and economically beneficial.

The way people relate to their physical belongings has changed drastically over the past century; wasted products are less likely to be repaired nowadays, and more likely to be disposed. Moreover, after disposal, unlike in pre-industrial society, waste is not given back to the land as an organic substance to enrich it. Quite often waste ends up contaminating the land because of the improper disposal. Nevertheless, treating waste as a resource is needed for societies’ and nature’s sustainability, and keeping and fostering this attitude is one of the main challenges within sustainable waste management.

2.2. THE VALUE OF WASTE AND CHALLENGES TO SUSTAINABILITY

The previous subchapter has settled the idea of historical and modern applicability of waste as a resource. Hence it is safe to assert that sustainable waste management on a community level has
to be a part of a bigger task, called sustainable resource management. Proper flow of resources in a community has to follow the principle of resource flow in ecosystems. Anderson et al. (1997, p.17) point: “In ecosystems the various flows are interlinked and waste from one organism is a resource for another. All materials flows are part of cycles. In a sustainable regime the same principle should apply to the functions of a community.” However, this principle was easier to implement for traditional settlements, where most of the needed goods were produced within a household, a farmhouse on the land. Most of the resources came from the farm itself, and the waste was “given back” to the ecosystem, therefore the resource cycle was quite short.

When it comes to sustainable material and resource flow in the society (and waste management in particular), there are certain requirements for flow patterns and volumes to be sustainable, economically viable and ecologically friendly in the long term. These requirements imply general reduction of material flows, and making them more cyclic. As stated by Zbicinski et al. (2007, p.157): “Today a very large share of the material flows is linear, from the origin to the waste dump. This is not sustainable. In the longer term we need to improve waste management to make the material flow more cyclic, and reduce the absolute amount of material used in our societies drastically.” Reducing resource flow, and particularly waste flow, is one of the main challenges for sustainable development.

There are several benefits of shorter material and resource cycles. Shorter resource cycles require less energy, and involve less pollution (Anderson et al. 1997). Contemporary level of urbanization and industrial development, however, leads to longer resource cycles, or, in vast majority of cases, simply linear resource flow, without a closed loop. A picture below illustrates the difference:

**Fig. 3 Resource flow patterns in sustainable and unsustainable society**

![Cyclic resource flow vs Linear resource flow](image)

Cyclic resource flow  
Linear resource flow

Nowadays the attitude towards waste as a useful resource is not put into practice, and therefore linear resource flows are dominating. For the sake of sustainability, cyclic resource flows and attitude towards waste as a resource need to be gained back. This can be done, for example, via implementing “life cycle approach”, which basically is built upon the idea of responsible planning of product’s life cycle, from cradle to grave, and preferably making it more durable, reusable, repairable and recyclable, with the aim “to keep a material in the highest grade application for as long as possible” (Zbicinski et al. 2007, p.161). Actually, Life Cycle Assessment methods started developing in the same time period of the 1970s, just as MSWM, because they are also aimed at sustainable resource flow and recycling of materials (Zbicinski et al. 2007, p.163). It is not always easy to plan and even track how resources are recycled from...
one product to make another, but the producers should make sure that the resources are bound to make a closed loop (even if it is long and the system including all the involved products is large and complex).

Valuable materials and resources from waste create additional flow and even a market, as they are bought and sold accordingly to stakeholders’ interests. Paper, glass, other household waste, and also metals – such as iron and copper scrap, for example, are used for production of new goods when possible. For instance, “scrap paper is used together with virgin fibres (about half of each) for new paper production. Paper factories thus buy return paper and of course for the cheapest price, wherever it is found” (Rydén et al. 2003, p.558). Industrial recycling of metals has been widely practiced already in the end of the 19th and the beginning of the 20th century, for low prices of used metal scrap and significant demand for metals in production. Also, recycling of metals saves resources and energy, for example recycling 1kg of aluminium saves up to 6kg of bauxite, 4kg of chemical products and 14 kWh of electricity (Waste Online 2012). Also, “recycling one tone of steels cans saves 1.5 tonnes of iron ore 0.5 tonnes of coal and 40% water usage” and “saves 80% of the CO₂ emissions produced when making steel from iron ore” (Waste Online 2012). The situation with a market for household waste is usually less obvious for a common sense, but the main actors in these markets are waste incineration plants, which turn waste into a resource for production of district heating or electricity. In Sweden, since not all the municipalities have their own waste incineration facilities, waste trading is common.

As a conclusion to this subchapter, the words from the report on World Waste Panorama study are cited from Veolia and CyclOpe (2009, p.3): “We must realize that part of our future depends on this waste: four billion tonnes are produced each year of which scarcely one-quarter is recovered or recycled at the present time: energy, compost, scrap, cellulose fibres, as many “secondary” materials which can substitute for the raw materials of which we are likely to run short before the end of this century. There is an echo here of the ancient dream of the medieval alchemists, who sought to transform lowly lead into precious gold, and who also sought to give some meaning to the “philosopher’s stone”.”

2.3. WASTE IN DIFFERENT SCHOOLS OF THOUGHT AS A CONTRADICTORY NOTION

Different disciplinary approaches towards the notion of waste are based on highlighting specific aspects of it, which are related to the focus of each discipline.

Law defines waste both through a physical definition, such as a list of substances which are considered to be waste, or through a formal logical definition, such as a famous European subjective definition through the waste holder, who discards or intends to discard objects (see above).

Economics constitutes the concept of waste as closely connected with the concept of a negative externality, as the production of waste is a “side-effect”, which definitely influences third parties, whose interests might have not been taken into account. “Both consumption and manufacturing activities generate waste with a negative impact on the wellbeing of populations (environmental pollution) outside any market context. … Through the introduction of taxes (impact on prices) or emission standards (impact on quantities), waste is attributed a value and externality a price” (Veolia and CyclOpe 2009). Moreover, depending on whether waste might be used as a resource for recycling or recovery, the value of waste might be positive or negative when it is exchanged (positive exchange value tends to grow with recent achievements in the field of technology,
which makes waste a useful material or resource again). A traditional enterprise minimizes the costs of waste management.

In human ecology, generation of waste is one of the aspects of relationship of humans with their environment, which is explained by social, economic and cultural activity. Therefore, the patterns of waste generation, disposal and management are first of all reflecting interconnectedness of humans with the environment. Problematic field for human ecology and waste studies would be focused around environmental impact of waste quantities and qualities, framed by social, cultural and demographic trends, like urbanization and population growth.

From sociological standpoint, waste-related studies mostly focus on power relations in the society it represents, and social inequality it reflects. The social meanings of waste are also subject to sociological research. Waste is treated as substance or object which represents the attitudes, behaviour and values of the waste holder. Contemporary composition of waste generated in Europe and the USA, with a high share of packaging waste and disposable products with short life span, is considered to be a reflection of a consumer society, corresponding to the values of people and their tendency to construct their social statuses through interactions, in which they are engaged into demonstrative consumption of goods and services. The system of waste redistribution is also tied with inequality and differences in social standards of living – especially from the standpoint of studies of conflict, viewing waste as a product of competition of different social groups over power.

These were simply several examples on how focus and emphasis might construct various and contrasting notions of waste from different scientific standpoints. It is important to mention that this paper is not focusing on finding the best way of defining waste in aspect of its embeddedness in social and economic life, and is targeted more on investigation into relations that waste generation and minimization have to some basic socioeconomic parameters.

Although waste is constituted differently in various scientific disciplines, one thing remains clear about it - “garbage is such a pervasive element in our society – there is a garbage angle to every human activity” (Rathje and Murphy 2001). The key idea of waste generation is expressed by archaeologists: waste is inherent to human life. This idea lets archaeologists make two major assertions about waste generation, which provide a solid background for the current paper:

First, “the creation of garbage is an unequivocal sign of a human presence” (Rathje and Murphy 2001, p.10).

And second, “if our garbage, in the eyes of the future, is destined to hold a key to the past, then surely it already holds a key to the present” (Rathje and Murphy 2001, p.11).

Logically these two statements imply, that if archaeologists and historians will be able to make conclusions about our society in the future, as they do now about our predecessors’ societies, then the waste we leave behind already reflects the parameters of contemporary society. And therefore it is valid to make a conclusion that our waste generation is probably influenced by some societal factors, which are going to be discussed in more detail further in the paper.
3. **WASTE GENERATION FACTORS ACCORDING TO PREVIOUS RESEARCH**

The current chapter is devoted to an overview of previous research on relation between socio-economic parameters and waste generation.

### 3.1. REVIEW OF LITERATURE AND PREVIOUS STUDIES ON THE TOPIC

The topic of waste generation factors has had previous attention, and several studies should be mentioned in order to provide necessary background for the current study.

The relation of MSW generation per capita and socioeconomic factors has been established long ago and confirmed by numerous studies. Already in the 1970s (which corresponds to the period when waste generation started to be problematic for “Western” societies of Europe and the USA) research projects were aiming to clarify the dependencies between waste generation and other societal parameters. For example, in 1974 in the USA Donald Grossman with colleagues published an article on “Waste generation models for solid waste collection” (Grossmann et al. 1974), where they employed econometrics to prove that waste generation is proportional to living standards. A year later, Kenneth Wertz, also in the USA, showed the dependency between waste generation and income (among other parameters) on the household level (Wertz 1976). In 1997, Medina publishes the article which is widely referenced to in waste management studies – “The effect of income on municipal solid waste generation rates for countries of varying levels of economic development: A model”, which also relates waste generation to income (Medina 1997).

As the field of studying waste generation factors developed, more sophisticated models evolved. For example, studies from the 1990s also related the amount of waste generated to such complex and operationalized parameters of population, as education, lifestyle (first and foremost consumption patterns), culture, etc (Al-Momani 1994).

Also, waste generation on national levels has been proven to correlate with population size (Grossmann et al. 1974).

Recent reports of Eurostat, such as “Generation and treatment of municipal waste” (Blumenthal 2011), mention these relations as evident, stating positive connections between GDP and waste generation, as well as between population growth and waste generation. Also, the report highlights that in 27 EU member states the amount of waste generation was slightly increasing, although in spite of it the implementation of the EU Waste Framework Directive and improvements in waste management regulations and technologies have decreased the amount of waste landfilled in recent years.

The relation of waste generation and composition to socio-economic factors was studied in various countries and cases. For example, the study on relation of waste generation to socioeconomic factors in *Sri Lanka*: although the study was conducted at the household level (not at the municipal level like the current one), with methodology based on regression analysis it showed that the quantity and composition of waste produced by a household are related to property value and income (Bandara et al. 2007). The case study of *Chile*, described in a thesis
of Ordóñez-Ponce and devoted particularly to assessing waste generation factors using artificial neural networks, had a broader aim of prediction of waste generation based on socio-economic factors (Ordóñez-Ponce 2004). The following parameters were included in the model: population, share of urban population, years of education, number of libraries and number of indigents, and they showed significant positive contribution to waste generation with high accuracy. Similar study was also conducted in Dhaka, Bangladesh (Rafia et al. 2010), and the results were published in Research Journal of Applied Sciences – the Bangladeshi research also claims that their results (from a sample study on household level, and ordinary least square regression analysis) prove dependency of waste generation on household level from household size, income, concern about the environment and willingness to separate the waste. In Malaysia, however, according to the study “The role of socio-economic and cultural factors in municipal solid waste generation: a case study in Taman Perling, Johor Bahru” (Yusof et al. 2002), some of these factors turned out to be questionable – neither income, nor education and other socioeconomic factors influenced waste generation at any significant level, while family size and family lifestyle had much greater impact. Of course, these conclusions relate to the level of households.

One of the most important studies which formed the framework for the current paper is the work by Chen Liu and Xin-wu Wu from Tongji University, published in 2011 in “Waste Management Research”. The paper presents a study on factors influencing municipal solid waste generation in China (Liu and Wu, 2011), and utilizes statistical analysis as well. The authors have chosen twelve parameters to include in their model: GDP, per capita GDP, urban population, the proportion of urban population, the area of urban construction, the area of paved roads, the area of urban gardens and green areas, the number of the large cities, annual per capita disposable income of urban households, annual per capita consumption expenditure of urban households, total energy consumption and annual per capital consumption for households. They divided these parameters into groups with the help of principal component analysis, and ended up with three major factors which influenced municipal waste generation: economy and urban development, energy consumption, and urban scale. The three components together accounted for 99.1% of the initial variance of waste generation, which indicates for a considerably successful modelling. Their main conclusions about the influence of these factors on waste generation involved a high role of “economy and urban development” factor, along with “urban scale”.

In Sweden, waste generation factors, especially on municipal level, were not yet studied from the standpoint of the current investigation. However, some research has taken place, and from recent projects, the one worth the most attention was a project by IVL Swedish Environmental Research Institute in collaboration with other organizations, which is called “Towards sustainable waste management” (Swedish Environmental Research Institute 2012a). The project covers broad goals of making waste management more effective and efficient by stimulating proper policy solutions and simultaneously adapting technological conditions for separation and collection of waste on the side of waste holders and recycling and treatment on the side of waste management. The project is subdivided into ten arenas, which have different focus and scope, such as policy formulation, or taxation, or future waste quantities (Swedish Environmental Research Institute 2012a), and the closest by content sphere to the present study is devoted to “Economic modelling for assessment of policy instruments”, which aims to “develop and apply tools for assessment of policy instruments on waste management” (Environmental Research Institute 2012b), by linking two models to each other – the model of Swedish economy and the model of Swedish national waste management, and making conclusions about how they actually interact. This idea corresponds to the idea of the present thesis; however without a doubt IVL has much more detailed modelling with a sharper focus on economic parameters and development, incorporating such variables, as growth, oil prices,
supply of labour force, technical development and many others. Unfortunately, the final results of the projects are not available yet, however its existence proves the viability of the idea of the present thesis: waste generation probably has interdependencies with social and economic parameters.

3.2. CONCLUSION ON WASTE GENERATION FACTORS

The brief review of previous research offers quite a range of various socioeconomic parameters, which hypothetically have correlations with waste generation at municipal level. Income, GDP, education, lifestyle, consumption, culture, family size, population size, population growth, share of urban population, urban scale, property value, economy and urban development, urban scale, energy consumption etc. were incorporated in models for waste generation factors by predecessors in the field of knowledge. Not all of them were or can be studied on municipal level (for example, GDP makes sense at national level, and family size only matters for household waste generation), and some of them are very hard to operationalize (such as lifestyle, culture or consumption patterns). Also, some of the parameters which are studied as waste generation factors, call for a different approach to analysis, such as psychological or purely economic standpoints.

The current thesis aims to cover the most basic socio-economic parameters of those which might influence waste generation and waste management. For this reason, and also considering data availability, the following parameters were chosen to participate in further analysis:

“Population size” – mean population size in the municipality, amount of residents;
“Age” – mean age of population in the municipality, years;
“Area” – the area of municipality, square km;
“Income” – mean value of disposable personal income for residents of the municipality aged 20-64, calculated on the basis of prisbasbelopp;
“Population density” – population density in the municipality, residents per square km.
4. EUROPEAN LEGISLATION ON WASTE MINIMIZATION

4.1. GENERAL DESCRIPTION

The EU Waste Legislation presents solid and complex body of directives (European Commission, EU Waste Legislation Overview, 2012), commission decisions, amendments and annexes. However, first and foremost, the main definitions, goals and priorities for the member states of the EU are set in the European Framework Directive on Waste, released in 2008. Waste Framework Directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives) sets to Sweden, as well as to the other member states, the goals of waste prevention and minimization. This Directive sets to the EU member states the general agenda, definitions and targets for waste management, and each and every member state is obliged to create and implement a national waste management plan in accordance with both goals set by the Directive and the state of the art in the country (for national waste management plan to be achievable and serving for improvement). If a country does not incorporate new waste management goals into its national law, it becomes subject to negative sanctions, such as fines, from the EU. Waste Framework Directive is accompanied by specific legislation and other directives, which regulate management of particular types of wastes, such as WEEE.


The third body of laws concerns specific waste streams, and includes a variety of Council Directives, covering aspects of management of waste oils, waste from titanium dioxide industry, agricultural use of sewage sludge, batteries and accumulators, packaging and packaging waste (the amount of normative acts regulating packaging is especially solid), disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT), end-of life vehicles, and, particularly, WEEE (European Commission, EU Waste Legislation Overview, 2012).

The release of the most important Directive, the Framework Directive itself, was preceded by the release of the Thematic Strategy on the prevention and recycling of waste. The Strategy was proposed by the European Commission in December of 2005 (European Commission, EU Waste Legislation Overview, 2012), and was one of the seven thematic strategies on environmental issues in the European Union, along with the Thematic Strategy on the Sustainable Use of Natural Resources (European Commission, Sustainable Use of Natural Resources, 2012). The Strategy on the prevention and recycling of waste aimed to help Europe become a recycling society that seeks to avoid waste and uses waste as a resource (European Commission, EU Waste Legislation Overview, 2012). “The aim of the strategy is to reduce the negative impact on the environment that is caused by waste throughout its life-span, from production to disposal, via recycling. This approach means that every item of waste is seen not only as a source of pollution
to be reduced, but also as a potential resource to be exploited” (European Commission, EU Waste Legislation Overview, 2012). Therefore, this strategy was an important step towards treating waste as a resource, promoting its recycling, reuse and recovery, and preventing negative impacts of its deposition and treatment. It set clear definitions of efficient recovery, recycling and safe disposal of waste, and introduces life-cycle thinking and integrated product policy approach. Hence, the Waste Framework Directive, which highly influences waste management plans and programmes in the EU member states and particularly in Sweden, has its origins in the Thematic Strategy on the prevention and recycling of waste.

The summary of the currently valid Framework Directive on Waste is presented below.

4.2. SUMMARY OF WASTE FRAMEWORK DIRECTIVE

The text of Waste Framework Directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives) includes 7 chapters and 5 annexes, which set clear framework and regulations for waste management and waste treatment in the European Union. The main intention of the Waste Framework Directive is to define key concepts of waste management, to set clear boundaries and to establish principles of minimizing negative impact from waste generation and treatment on environment and human health. The Directive encourages practical implementation of a waste hierarchy, obliges member states to create and follow waste management plans and waste prevention programmes, and to keep accounts and reports for various waste statistics as well. According to polluter-pays principle, the Directive also regulates the organization of waste economy in member states. The Directive also contributes to the goal of reducing the use of resources.

Chapter I states the main intention of the act, which is, as already mentioned, to lay down "measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use” (Article 1). The first chapter also sheds light on the scope of the subject matter of the Directive, excluding a list of substances which are out of the consideration. The Waste Framework Directive excludes from its consideration the following types of wastes and refuse: gaseous waste, land and contaminated soil, excavated land, radioactive waste, decommissioned explosives, sewage and waste water, mining waste covered by other legislative acts. Distinguishing between waste and by-products deserves special emphasis, as well as the end-of-waste criteria. The first chapter also contains the definitions of waste, waste management, prevention of waste, recovery, recycling, and other important notions. Waste is defined as “any substance or object which the holder discards or intends or is required to discard”, and waste management is “the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker” (Article 1).

Other key concepts, scope and definitions, which originate from the Framework Directive and are vitally important for the current investigation, but not included in the text itself, can be found in the Glossary in the Appendix to the current paper. The Appendix to this paper also contains Annexes I, II and IV from the Framework Directive on Waste, which are correspondently devoted to disposal operations, recovery operations, and examples of waste prevention measures.

Chapter II is devoted to general requirements to waste management in the EU member states. Rights of member states to operate under the Framework Directive and responsibilities of national actors of waste management are distributed in Chapter II. Extended producer
responsibility is encouraged, and particular appropriate measures to stimulate it are suggested – from acceptance of returned products and waste to informing about recyclability and re-usability of products and even increasing these qualities. (This fact also corresponds to the European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste.) Chapter II sets the goal of preventing waste, and therefore requires from member states a plan for waste management and even consumption patterns. It also sets targets of high level of recovery, re-using and recycling (of paper, metal, plastic and glass): for example, by 2020, these materials should be recycled at least at 50% level by weight. Demand for safe disposal operations is set in the Chapter II. General principle of safe and sound waste management, according to the Framework Directive, is the following: “waste management is carried out without endangering human health, without harming the environment and, in particular, (a) without risk to water, air, soil, plants or animals; (b) without causing a nuisance through noise or odours; and (c) without adversely affecting the countryside or places of special interests” (Article 1). The second important principle highlighted in the Chapter is polluter-pays-principle, which, being applied to waste management, requires all the costs of waste management to be borne by waste producers or by waste holders.

Chapter III is devoted to waste management itself. It lays down the choice of management scheme on the national level, as long as it generally fits the requirements from Chapter II. Even the responsibility for waste management might be spread in different proportions between original producers and holder, according to member states’ decisions. However, “any producer or holder of waste must carry out their treatment themselves or else must have treatment carried out by a broker, establishment or undertaking” (European Commission, EU Waste Legislation Overview, 2012). Main principles of measures of waste management are set as the following: self-sufficiency, proximity, and cooperation between member states where necessary. The chapter also pays attention to general principles of collection and treatment of hazardous waste, waste oils and bio-waste.

Chapter IV deals with permits and registrations for waste management quantities, types, technical requirements, allowances and operations. An important role also plays the obligation of member states to register all the establishments, firms, undertakings, dealers, brokers and organizations which perform waste management operations – all of them have to get a permit for such activity.

Chapter V is fully devoted to plans and programmes for waste management at local levels. All member states are required to have their national waste management plans, containing analysis of current situations and goals for the future in accordance with environmental and safety goals of the Directive. Member states are also required to have their own waste prevention programmes, which should be incorporated into waste management plans and have clear targets and indicators. Member states have to give all interested stakeholders a chance to participate in composition of the mentioned plan and programme.

Chapter VI imposes regulations on inspections, record keeping, enforcement and penalties in the sphere of waste management.

Chapter VII, which is named “Final provisions”, is devoted to obligations connected with reporting and reviewing on implementation of the Waste Framework Directive, transposition of it and other legal procedures. These two chapters cover rather administrative and legal aspects of waste management, than substantial issues, and therefore are not summarized in the current review.

4.3. IMPORTANT FEATURES

The most important features from the other waste legislation of the EU (on waste management operations and specific waste streams) by relevance to the current investigation are the following:

**Landfill restrictions**
Landfill is regulated and seriously restricted by Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (European Union, Waste management legislation summaries, Landfill, 2012) and related acts, which define different types of waste and regulate allowed landfill operations for them in accordance with the goal of minimizing negative effects of landfills on the environment. The main requirement is treatment of waste before it reaches landfill stage, and separating hazardous waste to special landfill sites. It also bans the following categories of waste from landfilling: liquid, explosive, flammable, medical contagious waste, tyres, and several other types according to Annexes. The Directive also clarifies requirements for acquiring a permit for landfilling operations.

**Incineration and regulation**
Waste incineration is regulated by the Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (European Union, Waste management legislation summaries, Waste incineration, 2012), and the main focus of it is preventing adverse effects of waste incineration and corresponding emissions by obliging all the operating plants in the field to fulfil technical requirements (on incineration process conditions and air emissions) in order to get a permit from a competent authority to proceed. The heat, which is generated by the incineration of waste, is recommended to be used.

**Biodegradable waste**
Bio-waste is managed differently in the EU member states, however there are regulations and recommendations of the EU on this (European Union, Waste management legislation summaries, The management of bio-waste, 2012). Landfilling is considered to be the least favourable option because of methane emissions, some of bio waste types and not accepted to landfills. Separate collection of bio-waste is encouraged to use composting method. Incineration with energy recovery is allowed, however favoured less than biological treatment. Sweden, for instance, has introduced landfill ban for bio-waste in 2005 and has high levels of compost separation compared to other EU member states, according to Blumenthal (2011, p.5).

**Packaging waste**
Packaging and packaging waste falls under European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste (European Union, Waste management legislation summaries, Packaging and packaging waste, 2012), and related acts and amendments. The essence of requirements to packaging waste is significant increase of recycling and energy recovery share, the marking and identification of packaging material for easier recycling by consumers, and limitations to weight and volume to acceptable minimum.

**Waste electrical and electronic equipment (WEEE)**
Is an important waste stream within EU, and although WEEE is excluded from the scope of the current paper, it deserves mentioning nonetheless. WEEE falls under Directive 2002/96/EC of
the European Parliament and of the Council of 27 January 2003 on waste electrical and
electronic equipment (European Union, Waste management legislation summaries, Waste
electrical and electronic equipment, 2012), which mainly emphasizes producer responsibility for
all stages of life cycle of electrical and electronic equipment, from reusable and recyclable
design, to best available technologies for treatment, recycling and recovery of WEEE. It also
obliges EU member states to create all the conditions for separate and free collection of such
wastes, and give producers rights to organize their own take-back systems.

4.4. CONCLUSION ON WASTE MINIMIZATION STEPS

The current research treats the concept of waste minimization and waste minimization steps in
full consent with the EU waste hierarchy – and thus, they are reducing, reusing, recycling, and
recovery, with the last step in the waste hierarchy, landfilling, not being technically a waste
minimization step. However, as already mentioned in the description of delimitation of the
current research, reusing is deliberately omitted from consideration in the practical part, as
reusing is hardly measurable on municipal level (maybe reusing is measurable on household
level, however it is too vague for easy operationalization and most probably requires qualitative
methods of studying). Also, as reducing is not measurable, reducing within the current paper
would be inverted and measured simply as waste generated, assuming that the bigger the amount
of waste generated and collected, the lower was reduction of waste, proportionally. Recycling
and recovery are taken into analysis as correspondent amounts per capita.
5. Framework and Goals of Waste Management in Sweden

Goals and general framework for Swedish waste management are set by the EU Waste Legislation, which is discussed above, and also Swedish national law, with participation of Swedish Environmental Protection Agency (Naturvårdsverket), and relevant plans and agenda accepted as a goal by main actors of waste management, like the current vision of Avfall Sverige, named “Det finns inget avfall”, or “Zero Waste” in English (Avfall Sverige AB 2011b, p.5).

Swedish waste management acknowledges the following hierarchy of waste, which is shared by all the member states of the European Union: prevention of waste, re-use, recycling, recovery (such as, for example, energy recovery), and disposal, according to the Waste Framework Directive (Article 4). Hierarchy implies priorities and importance of these steps in waste management.

The general approach to waste management in Sweden can be characterized as based on values of environmental protection, sustainability, economic viability, resource saving, advanced technical solutions, and human health. The following part is devoted to more detailed description of general legal framework and regulation of waste management in Sweden.

5.1. The Swedish Parliament and the Swedish Government

Following the previous part, which provided an idea of main European standard and goals for waste management, this part is introducing new directions for improvement and development for Swedish national waste management system, which were proclaimed by the Swedish Parliament and the Swedish Government. According to the Framework Directive, waste prevention, minimization and increasing share of recycling and recovery are also among these goals. Waste recovery to energy is already well developed in Sweden, as well as WEEE treatment and recovery to biogas and digestate (Avfall Sverige AB 2011a, p.5).

Some of broad waste-related legal requirements are set by the Swedish Parliament, Riksdag, and incorporated into 16 environmental objectives of Sweden. Proper and safe waste management and resource saving contribute to implementation of the most of the goals, and especially to the goal of «good built environment», which has waste-related parameters in its indicators (Sweden’s Environmental Objectives Portal 2012b). The objectives have been revised by Riksdag in 2010, therefore Sweden’s current targets for sustainable development are up-to-date.

The main requirement to waste-related indicators of Riksdag’s 16 environmental quality objectives is not increasing amount of waste generation and taking maximum use of waste resource potential, simultaneously minimizing health and environmental effects and associated risks (Sweden’s Environmental Objectives Portal 2012a). More specifically, the goals to achieve are reduction of waste disposed, increasing share of recycling, material and energy recovery, and biological treatment, and special attention to recovery of phosphorus compounds from wastewater. From these goals, by 2010 the reduction of landfills and the increasing recovery of phosphorus have been met. However, other goals are estimated as more complicated and time-taking to achieve according to the Sweden’s Environmental Objectives Portal (2012a).
The legislation, regulating waste management in Sweden, is produced by Miljödepartementet of the Swedish Government, which is the Ministry of the Environment. Recycling and waste are within the scope of their authority and responsibility, and according to their vision and 16 environmental quality objectives of Sweden, recycling plays a very important role in addressing environmental problems (Sweden’s Environmental Objectives Portal 2012a). The main message of the Ministry of the Environment argues that “healthy competition and accountability among stakeholders in the waste market are key elements in preventing products negative impact on the environment and human health” (The Government of Sweden, Recycling and Waste, 2012).

The Ministry is responsible of implementation and control of environmental goals set by Riksdag, and their waste policy is built upon recognition of high waste production due to consumption and production of goods and services (The Government of Sweden, Ministry of the Environment, 2012), and therefore strives for introducing systems of control and engagement of different actors. The idea is treating waste as a useful resource, minimizing its negative impacts, paying special attention to phosphorus recycling according to Naturvårdsverket proposal, and combating litter. Moreover, renewed waste regulation was released in August of 2011 (the official document is Avfallsförordning – the Waste Ordinance - 2011:927), to fit the requirement of the European Framework Directive on Waste, which is described in the previous chapter. According to the Swedish EPA Naturvårdsverket (Naturvårdsverket, Laws and Regulations on Waste, 2012), the new details of it are a number of new definitions, transportation rules, regulations on waste oils and requirements for the national waste management plan and waste prevention programme. Generally, the Waste Ordinance follows the European Directive closely (Notisum AB 2012), with the difference of containing more details and specificity.

For example, important features of Swedish waste policy are landfill taxes and prohibition of landfilling of burnable and organic waste (Naturvårdsverket, Policy instruments for sustainable waste management, 2012), in order to minimize negative impacts on the environment. Landfilled waste is taxed since 2000, and Naturvårdsverket claims that it had shown good results for extension of recycling share (Naturvårdsverket, Policy instruments for sustainable waste management, 2012). The ban on landfilling of burnable waste was introduced in 2002, and three years later the ban on landfilling organic wastes followed, as a stimulus to collect it separately. Moreover, later incineration of waste also became subject to taxation, depending on the fossil content in wasted material.

As the Swedish environmental laws are in fact proposed to the Swedish Government by Naturvårdsverket, the next part of the paper is devoted to this organization and their vision of waste management in Sweden.

### 5.2. NATURVÅRDSVERKET: THE SWEDISH ENVIRONMENTAL PROTECTION AGENCY

The Swedish Environmental Protection Agency, as a governmental agency, exists to propose and assist in putting into practice environmental policies in Sweden, since it was founded in 1967. “The Swedish Environmental Protection Agency coordinates follow-up, provision of information and the use of economic impact assessments within the environmental objectives system”, according to the Sweden’s Environmental Objectives Portal (2012a). “One goal of the Swedish Protection Agency is to reduce the impact on the environment from the complete lifecycle of products – from raw materials to waste. We have a particular responsibility for an efficient legal
framework and for effective policy instruments” (Naturvårdsverket, Products and Waste, 2012). The Swedish EPA, on behalf of the Swedish Government, is responsible for proposing environmental policies, implementation of them, and control of stakeholder’s documentation and efforts towards it.

According to information from Naturvårdsverket (EU and international cooperation, 2012), “environmental work in Sweden is to a large extent based on decisions taken within the EU and through active cooperation in international organizations. Experts from the Swedish EPA participate in more than 150 working groups within the EU and some 90 groups in international organizations and multilateral environmental agreements.” They also claim (Naturvårdsverket, Swedish EPA in the EU, 2012), that “most of Sweden’s environmental legislation is developed in the context of the EU. The EU also drafts numerous strategies for its future environmental activities. The environment is in fact one of the areas of policy-making in which the influence of the EU is most pervasive, with at least 250 common legislative instruments. EU work is thus a central part of the Swedish EPA’s activities.” Therefore, a lot of the proposals and ideas which are developed at Naturvårdsverket are initially coming down from the European Union, and particularly the EU Framework Directive on Waste. This is confirmed by the list of general goals of EPA in the area of waste management, which are promoted on their website – following waste hierarchy, reduction quantities of waste, using waste efficiently as a resource, decreasing environmental impact from waste management and increasing producer’s responsibility (Naturvårdsverket, Objectives, strategies and results, 2012).

The most recent proposal of Naturvårdsverket to the Swedish Government is a new national waste management plan, which is called "From waste to resource - Sweden's Waste Management Plan 2012-2017" (Naturvårdsverket, Ny nationell avfallsplan, 2012). The plan is going to be completed by the end of February 2012, in accordance with expert comments and remarks. This waste management plan was developed by Naturvårdsverket to fulfil the EU Framework Directive on Waste requirement, and also Naturvårdsverket works to create waste prevention programme for Sweden in 2013. The main emphasis of the plan by 2017 is on five substantial areas of responsibility within the field of waste management, which are “waste in construction sector, household waste, resources in the food chain, waste treatment and illegal exports of waste to other countries” (Naturvårdsverket, Ny nationell avfallsplan, 2012). The plan’s goals imply cooperative efforts of all actors involved, which are municipalities, agencies, producers and researchers. The plan provides individual instructions to actors accordingly to every set goal.

5.3. “DET FINNS INGET AVFALL”, OR “ZERO WASTE” VISION

“Zero Waste” originates from one of the main actors of Swedish waste management, the branch organization for actors of waste management in Sweden, Avfall Sverige AB, which cooperated with Swedish municipalities in the field of waste management. Work on the vision started at the annual meeting in 2010, and the proposal was approved in 2011. “Zero Waste” (Avfall Sverige AB 2011b) sets long-term targets for waste management until 2020, and two main accents of it are, first, breaking the relationship between waste and growth, and, second, achieving strong upward movement in the waste hierarchy. According to the vision, municipalities remain main actors of socially and environmentally responsible approach to waste management. Main points, according to the vision, are the crucial role of municipalities in achieving goals for 2020, and their ability to present interests of both public sphere and citizens in sustainable waste management. The vision requires municipal waste sector to be leading the society towards new approach to waste management, characterized by constant setting higher aims to the whole waste
industry (in spite of widespread and grounded belief that Swedish waste management is already at the very good level environmentally and socially).

5.4. CONCLUSION ON FRAMEWORK, GOALS AND ACHIEVEMENTS OF SWEDISH WASTE MANAGEMENT

Although the present review only covers the key aspects of the framework of Swedish waste management, the main features have been highlighted at every level of legal regulations and state of the art in waste management in Sweden.

The main direction and priorities are set to Sweden by the European Union waste legislation, and, more specifically, by the EU Waste Framework Directive. The most influential local actor of waste management policy within the country is Naturvårdsverket, which is very active in setting and monitoring the fulfilment of goals. As Naturvårdsverket pays a lot of attention to the EU environmental legislation and directives, and incorporates all of them into proposals for Swedish policies and legislation, the goals within waste management frameworks described above are very consistent and not at all contradictory.

In conclusion on the goals and targets of Swedish waste management, it is vital to state, that at all the levels of goal-setting these aims are emphasized:

- Managing waste without endangering human health or harming the environment;
- Following the waste hierarchy, with special emphasis on the highest step of it - waste prevention;
- Clearly allocating social, economic and environmental responsibilities to waste management actors, with extended producer responsibility;
- Increasing share of recycling and recyclability;
- Improved planning and monitoring of waste management.

And even though Sweden is a bright example of a successful waste management system, with a positive recent trend or decreasing waste quantities, “it is imperative however, not to forget the important task of taking care of the waste that is generated, despite all prevention efforts” (Avfall Sverige AB 2011a, p.5).
Having outlined the main features and priorities of the legal frame of waste management in Sweden, the current thesis turns to actual state of the art and organization of waste management. This chapter is devoted to types of entities and organizations, which actually perform waste management, rather than legal authorities and requirements.

6.1. ACTORS OF SWEDISH WASTE MANAGEMENT

Main actors of Swedish municipal solid waste management (MSWM) are municipalities (and this is exactly the reason why the analytical part of the current research is focusing on data on municipal level). Municipalities are local authorities, according to Sweden’s administrative division, which are responsible for, besides waste management, social services, school system, childcare, care of the elderly and the disabled, water and sewage, safety and other vital needs of local society (Swedish Association of Local Authorities and Regions 2012). There are 290 municipalities in Sweden, and when it comes to their performance in aspect of waste management, they are allowed and therefore practice uniting their efforts at some of the stages of waste management process. Within the waste management itself, municipalities have responsibilities within collecting, treating and processing municipal solid waste, except for waste which is managed under the producer responsibility. More importantly, being responsible for the municipal solid waste, municipalities also are free to choose waste management options from options that are legal. Within their collaboration with producers, municipalities are also obliged to monitor and control measures within extended producer responsibility (hereafter – EPR), and communicate information about waste collection points to households.

The role of producers in both generation and then management of waste is crucial. With the approach of extended producer responsibility (EPR), which is usually defined as one the strategies serving to force manufacturers to design their products with a thought about resource-saving, that way so the producers are responsible for the costs of taking care of waste from their products at the end of life cycle, producers’ role has been increasing over the recent years. Due to Naturvårdsverket (Producer responsibility, 2012) Sweden has introduced compulsory producer responsibility in five areas: packaging, tyres, newsprint, vehicles, and WEEE (electrical and electronic products). Also, the producers of office paper, as well as building industry, have voluntary producer responsibility. Introduction of producer responsibility in Sweden showed good results with material recycling. EPR is a very promising alternative to MSWM when it comes to dealing with product wastes (Spiegelmann and Sheehan 2005). (Within broader EPR agenda, product wastes management system is an extension of the production and consumption system, which seems reasonable and leaves mostly biowaste to MSWM.) According to the report of Naturvårdsverket on EPR (2005), EPR requires very detailed regulation in order to achieve its goals of reducing waste and increasing recycling, as otherwise responsibilities are not clearly distributed between actors.

Under the Environmental Code of Sweden, producers must ensure that waste is collected, transported, recycled, reused or disposed of in a way that is harmless in aspects of health and environment. For manufactured commodities and their packaging, producers have to provide information on material composition and ensure that they have certain reusability or recyclability. Under regulation on packaging (Förpackningsförordningen), producers must provide systems for collection of packaging waste associated with their products, so that it is recycled and disposed environmentally sound. They also have to follow the targets set for share of
recycling of each type of packaging waste, which is about 80% on average. Therefore producers have to ensure that waste associated with their products is collected, reused, recycled and disposed safely, and report on it to EPA (Naturvårdsverket 2005).

There are organizations, which are built up by producers and take responsibility for collection of packaging waste are called “materialbolag”, or material companies. As according to regulation on recycling producers may form associations to deal with their obligations, material companies are a form of such associations. For example, manufacturers of newsprint have launched Pressretur AB. There are such companies in other fields, too, such as Svenska Metallkretsen AB, Plastkretsen AB, RK Returkartong AB, Svensk GlasÅtervinning AB and Svenskt Returträ AB. Such companies organize collection, transportation and sorting of waste under producer responsibility, and also inform citizens about sites and systems for waste collection. Material organizations also collaborate, and form bigger service organizations, which, for example, deal with issues of leasing land from municipalities, or administer financial questions of waste collection and recycling. As example is REPA.

Another important actor of the Swedish waste management is Avfall Sverige AB – Swedish Waste Management, and moreover, this stakeholder is also very important for the current investigation, as Avfall Sverige provided waste-related data on municipal waste management performance from their web-based statistics system Avfall Web. Avfall Sverige – Swedish Waste Management is a branch organization within the field of waste management and recycling. The mission of Avfall Sverige is to monitor how Swedish waste management works, for the sake of environmental safety, sustainability and long-term goals. The mission implies also influencing decision-makers in the field, increasing knowledge and competence, and collaboration with EPA, the Ministry of Environment, other authorities and organizations, and business representatives (especially on the subject of extended producer responsibility). Avfall Sverige has international contacts, collaborates with equivalent enterprises in the Nordic Union, is a member of Municipal Waste Europe and participates in International Solid Waste Association activities.

One more set of actors is a number of private companies, which provide services in waste industry. Avfall Sverige AB provides this information in the report (2011a, p.4): “In 75% of Swedish municipalities, external actors, private companies, manage household waste collection, while in the rest of the municipalities provide this service. Waste treatment is performed either by the municipalities themselves or by an external actor, often a municipal enterprise or sometimes a private company.” These companies perform, for example, transportation, curbside collection, or treatment of waste.

Also, households are important actors in waste management. Their responsibilities are “sorting their waste and delivering it to the appropriate place” (Naturvårdsverkter, Responsibility for waste, 2012).

6.2. WASTE MANAGEMENT SYSTEM AND THE VARIETY OF METHODS

Waste in Sweden is managed by actors described above, and according to waste hierarchy. The most important treatment methods for waste are material recycling, biological treatment (anaerobic digestion or composting), incineration waste with energy recovery, and landfilling. Collection and transport of waste can have various forms, depending on municipality and private companies operating. For example, some municipalities collect food waste from households
separately from combustible waste. In some cases bags of different colours are used for food waste and combustible waste, so optical sorting can take place. Curbside collection is present in the regions with single-family houses. Bulky waste is usually left by residents at manned recycling centres, as well as WEEE and hazardous waste. Collection and transportation systems employ the whole range of various technologies from usual trucks to underground containers and vacuum collection.

However, as the current investigation only deals with the data on municipal level, which are already aggregated, there is no need to provide all the details about waste collection, transportation and treatment methods variety.

6.3. AMOUNTS OF WASTE PRODUCED, TREATED AND DEPOSITED IN SWEDEN

According to the reports from Naturvårdsverket (Producer responsibility, 2012) and Avfall Sverige AB, waste management improved in the past decade. More precisely, in the last 12 years, the amount of waste which is recycled or recovered in some other way increased from 70 to 98 percent. Particularly, material recycling increased from 2 to 35 percent, biological treatment increased from 7 to 14 percent, and incineration with energy recovery grew from 36 to 48 percent. Landfill, correspondently, has decreased from 31 to 1 percent. These improvements were possible due to household participation in active sorting simultaneously with technological and infrastructure developments. However these are shares, and in absolute amounts the amount of waste generated has increased from 3.678.000 tons in 1997 to 4.486.000 in 2009, which is a 22% growth (sopor.nu, Svenskarna återvinner allt mer, 2012). The negative trend of waste generation broke just recently, in 2010 and 2011 each year less waste was generated than during previous year. The reduction presents only 2,7 percent in 2010 compared to 2009 (Avfall Sverige AB 2011a, p.4). Therefore no long-term and solid conclusions should be drawn; however these results are inspiring to waste management decision-makers.

**Fig. 4 Total quantity of treated household waste in 2006-2010, according to Avfall Sverige**

Data source: Annual report of Avfall Sverige “Swedish Waste Management 2011”
Some more detailed figures from 2010 and 2011 are provided below to illustrate that waste problem still involves significant amounts of waste.

According to informational website sopor.nu, which is devoted to popular explanations and facts about waste in Sweden, just household waste which was collected and treated in 2010 in Sweden accounts for 4.364.000 ton (sopor.nu, Svenskarna återvinner allt mer, 2012), which, calculated per capita, would constitute 463 kg. Compared to the previous year, the amount decreased a little, as in 2009 per capita waste generation was 480 kg. From these amount, 36% went to material recycling, 13% went to biological treatment, 49% was incinerated with energy recovery, and only 1% went to landfill (which is remarkably small share compared to many other countries even within the EU). The remaining 1% presents hazardous waste which was treated separately with special methods and technologies.

EPR, according to sopor.nu (Statistik över olika avfallsslag, 2012), is also bringing about significant results, for example 359.000 ton of newspapers and other printing industry production were recycled under producer responsibility. Paper and carton packaging was recycled in amount of 116.000 ton in 2011. Recycled metal packaging in 2011 accounts for 16.000 ton, while plastic packaging was collected in amount of 46.000 tons, and glass packaging was 183.000 tons in amount. These figures are preliminary (as they relate to year 2011, which is relatively recent to draw final conclusions. However even these figures are considered to be relatively high compared to other countries.

WEEE, according to branch organization El-Kretsen, was collected in the amount of 154.185 tons in 2011, which corresponds to 16,27 kg per person. This is relatively high compared to the 4 kg per person, which are average for the EU member states.

Food waste and garden waste in 2010 was collected in the amount of 587.179 tons, and treated by composting or anaerobic digestion. In the same year of 2010, 2.123.680 tons of household
waste was incinerated with energy recovery. As already mentioned above, only 1% of household waste was landfilled. In absolute values it accounts for 42,000 tons, and it also presents a decrease compared to year 2009.

Tires are collected under EPR, however accounted as industrial waste. Responsible organization “Svensk Däckåtervinning” reports that over 90% of tires are returned back (sopor.nu, Statistik över olika avfallsslag, 2012), of which some are subject to retreading and recycling, and some are subject to incineration with energy recovery. Compared to other European countries, as already mentioned, Sweden has high rates of recycling and recovery (sopor.nu, Svenskarna återvinner mycket jämfört med övriga Europa, 2012). Also, Sweden has really low amounts of per capita landfill – 25 kg per person compared to 213 on average in other EU member states. Only the Netherlands, Belgium and Germany landfill less waste than Sweden per capita.
7. METHODOLOGY

7.1. TASKS AND MODELS

As the current research is exploratory, its methodology is designed as an effort to find dependencies between waste generation, waste minimization and socio-economic parameters. Also, the methodology of the current research is based on the goals to achieve.

The first objective of the current research, the description of the current system of waste management in Sweden with emphasis on priorities of waste management, waste minimization measures, and quantities of waste produced, was fulfilled in the previous theoretical chapters.

The second objective of introducing socio-economic variables which might influence waste minimization and waste generation, as well as introducing variables representing these concepts, is also met, and the basis for the suggested variables is a combination of previous research and description of Swedish waste management.

To check the presence of dependencies between variables, correlation analysis is employed. After this basic step of exploring correlations between variables, multiple regression models will be built in order to verify whether the dependencies between variables can be modelled using causal relations, and whether any of key parameters can be explained via a combination of other parameters.

The goals of regression analysis as a method, among others, are:

- defining to which extent the variation of dependent variable is explained by independent variables;
- defining the input of each independent variable into dependent variable’s variation.

These two goals correspond to the goals of searching for interdependencies and causality between variables.

Methodological delimitations and assumptions of multiple regression based on ordinary least squares method of calculation are:

1. Representative sample (and in case of the current study, where the sample is the universe, but contains missing data, the main requisite is that the sample should not be biased because of the missing data).
2. Interval or ratio scales by level of measurement of variables.
3. Variables are measured without error, or the measurement error is not significant and not systemic.
4. Absence of systemic error (error should be random and with a mean of zero instead).
5. Absence of multicollinearity of independent variables (they are not correlated).
6. Homoscedasticity (constant variance of error across observation, as otherwise data would not fit under one and the same model).
7. Relations between independent and dependent variables are linear.
8. Regression model implies not only correlations (meaning mutual interdependency), but a second level of this dependency – causality. Therefore when modeling, causality and causal structure of the model are inherent, too – we are aiming to explain the behavior of
independent variables by behavior of dependent variables and we already impose causal structure to our assumptions.

Some of these delimitations are fulfilled by default (such as, for example, level of measurement), some should be tested further, either to prove that they are fulfilled, or to see whether they can be taken as an assumption.

To build regression models, several parameters, based on both theoretical investigation and data availability, were introduced. The table below presents the parameters and descriptions of corresponding variables, which might be used in explorative analysis:

<table>
<thead>
<tr>
<th>Group</th>
<th>Name of variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste generation</td>
<td>Amount of collected household waste and similar to household waste (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of collected waste in bins and bags (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of collected bulky waste (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of collected packaging and newspaper material (kg/person)</td>
</tr>
<tr>
<td>Socio-economic factors of waste generation</td>
<td>Income (median disposable income of people between 20 and 64 years old), prisbasbelopp</td>
</tr>
<tr>
<td></td>
<td>Mean age (by year of birth), years</td>
</tr>
<tr>
<td></td>
<td>Population size, persons</td>
</tr>
<tr>
<td></td>
<td>Area, km²</td>
</tr>
<tr>
<td></td>
<td>Population density, inhabitants per km²</td>
</tr>
<tr>
<td>Recycling</td>
<td>Amount of household waste for recycling (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Percentage of food waste from “big kitchens” which is recycled by biological treatment (%)</td>
</tr>
<tr>
<td></td>
<td>Percentage of household waste that is recovered through recycling, including biological treatment (%)</td>
</tr>
<tr>
<td>Recovery</td>
<td>Amount of household waste for incineration (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of household waste to central biological treatment (kg/person)</td>
</tr>
<tr>
<td>Landfill</td>
<td>Amount from landfill residues from households (kg/person)</td>
</tr>
</tbody>
</table>

Usually the reduction of the amount of independent variables improves the credibility of the model. This idea of reduction is especially important when independent variables are substantially very close to each other, which increases the risk of multicollinearity.

### 7.2. DATA COLLECTION, SOURCES AND AVAILABILITY

The data for the present study originates mostly from a database collected by Avfall Sverige, which is available online to registered members of Avfall Sverige network at Avfall Web (avfallweb.se). Avfall Web is an online statistical resource on waste-related information on municipal level, which serves for monitoring and benchmarking Sweden’s waste management performance. Participation in data submission is voluntary, about 75% of municipalities have contracts with Avfall Sverige. However, the amount and detailization of data provided to Avfall Web significantly differs from one municipality to another (and this fact has a tendency to create a problem with data availability, which is discussed in the next chapter). The data, which was extracted from database’s user interface, covered three broad informational units – Insamling (Collection), Återvinning/Behandling (Recycling and Treatment), and Deponering (Landfill).
The level of detalization was chosen as first and basic, especially considering extremely low data availability for higher detalization. Time span available in the database covered a period from 2007 to 2011, however 2011 had to be taken away from the database for the lack of corresponding data on other than waste-related parameters. All waste-related data are presented either as share, or as amount per capita, no absolute figures are participating in the analysis for the reason of municipalities having different population numbers.

Within the current paper, for basic socioeconomic parameters representing factors of waste generation, data from Statistiska Centralbyrån (hereafter - SCB) were used. Databases are available and can be reached online (ssd.scb.se/bjssd/sok_link.asp?sokord1=efter+kommun&xu=c5587001&yp=duwird&lang=1). SCB has data on all 290 municipalities, however data for year 2011 are missing for most of the parameters yet.

There are 20 of 290 municipalities, which are not covered by the database made for the current thesis, either because they are simply missing from Avfall Web, or because they have formed unions for waste management which do not correspond to municipal division. For the confidentiality agreement with Avfall Sverige, that all the data is only presented at aggregated level, the list of 20 initially missing cases is not presented in the paper. However within the expert assessments, it has been assumed that these 20 cases do not have any specific common features neither in waste management aspects, nor in socioeconomic performance, therefore bias is very unlikely. To create the database, these cases were cut out from files, and then files were accurately merged. The final database, before quality check and missing values clean-up, contains 1080 cases (4 years of 2007-2010 for 270 municipalities).

7.3. METHODS AND THE PLAN OF ANALYSIS

The analysis is to be performed using the methods of correlation analysis and multiple linear regression, with the help of SPSS statistical package. Using these methods is possible because of high level of measured scales for all the collected data. Values are ratio and allow all the mathematical operations.

The analysis, considering also some requirements the method of regression analysis has, and methodological delimitations, has to proceed in the following steps:

1. Checking the consistency, structure and quality of data.
2. Analysis of missing data.
3. Correlation analysis.
4. Checking whether the prerequisites and assumptions of the methods are fulfilled.
5. Regression analysis. Assessment of model quality.
6. Drawing conclusions.
8. ANALYSIS AND INTERPRETATION OF RESULTS

8.1. DATA CONSISTENCY AND QUALITY

The database for analysis was compiled from several files obtained from AvfallWeb and SCB. Upon deletion of 20 municipalities which were not represented in AvfallWeb for the lack of contract with them, and merging databases together, random manual check of 30 cases took place, in order to verify that the merging process didn’t create any technical error and figures in the database actually correspond the right cases and variables.

The first stage of working with a database after compilation and checking that data were copied correctly from initial sources is data consistency and quality check.

The background research provided 15 variables which are potentially usable for the current research (besides the variables “municipality” and “year” which are in the database to give extra identification to the case number).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Working Name</th>
<th>N</th>
<th>Valid</th>
<th>Missing</th>
<th>Share of missing values (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>municipality</td>
<td>municipality</td>
<td>1080</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>year</td>
<td>year</td>
<td>1080</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Amount of collected household waste (waste from households and similar waste from other activities) (kg/person)</td>
<td>CW_HouseholdSimilar</td>
<td>569</td>
<td>511</td>
<td>47.3</td>
<td></td>
</tr>
<tr>
<td>Amount of collected waste in bins and bags (kg/person)</td>
<td>CW_BinsBags</td>
<td>725</td>
<td>355</td>
<td>32.9</td>
<td></td>
</tr>
<tr>
<td>Amount of collected bulky waste (kg/person)</td>
<td>CW_Bulky</td>
<td>672</td>
<td>408</td>
<td>37.8</td>
<td></td>
</tr>
<tr>
<td>Amount of collected packaging and newspaper material (kg/person)</td>
<td>CW_PackagingNewspapers</td>
<td>627</td>
<td>453</td>
<td>41.9</td>
<td></td>
</tr>
<tr>
<td>Amount of household waste for incineration (kg/person)</td>
<td>HW_Incineration</td>
<td>589</td>
<td>491</td>
<td>45.5</td>
<td></td>
</tr>
<tr>
<td>Amount of household waste to central biological treatment (kg/person)</td>
<td>HW_Biotreatment</td>
<td>562</td>
<td>518</td>
<td>48.0</td>
<td></td>
</tr>
<tr>
<td>Amount of household waste for recycling (kg/person)</td>
<td>HW_Recycling</td>
<td>206</td>
<td>874</td>
<td>80.9</td>
<td></td>
</tr>
<tr>
<td>Percentage of food waste from households, restaurants, caterers and retailers which is recycled by biological treatment (%)</td>
<td>Procent_Biotreatment</td>
<td>514</td>
<td>566</td>
<td>52.4</td>
<td></td>
</tr>
<tr>
<td>Percentage of household waste that is recovered through recycling, including biological treatment (%)</td>
<td>Procent_HW_Recycling</td>
<td>169</td>
<td>911</td>
<td>84.4</td>
<td></td>
</tr>
<tr>
<td>Amount of landfill residues from households (kg/person)</td>
<td>Landfill</td>
<td>593</td>
<td>487</td>
<td>45.1</td>
<td></td>
</tr>
<tr>
<td>Average population (person)</td>
<td>Pop</td>
<td>1080</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>Age</td>
<td>1080</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Population density (inhabitants per km²)</td>
<td>Density</td>
<td>1080</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>Area</td>
<td>1080</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>------</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</td>
<td>Income</td>
<td>1080</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

There are two blocks of variables which have different data quality. 10 variables in gray colour relate to waste management and were provided by AvfallWeb, while 5 other variables relate to basic socio-economic characteristics of a municipality and were obtained from SCB. The 5 socio-economic variables have zero share of missing values, while waste-related data is of lower quality than expected, with very high shares of missing values for each of the variables.

Actually, data from SCB under preliminary research also showed drawbacks, such as absence of the most recent year 2011, and also high share of missing values for some of the secondary parameters that were initially candidates to be included in the analysis (such as energy consumption by type of use and type of energy). However within the current analysis with a time span until 2010, waste-related data seem to create a lot more problems with quality than socio-economic parameters. Missing values analysis will follow prior to choosing a method of treatment of missing values. Data consistency is to be checked first.

Socio-economic group of variables (from SCB) have all values for 1080 cases (270 municipalities in 4 years). Variables were sorted and checked for peaks, to see whether the values are realistic and the peaks of minimum and maximum can be explained. The data don’t include any unrealistic or extreme values for socio-economic or waste-related parameters.

Waste-related group (from AvfallWeb) has a lot of missing data, as according to the manual of Avfall Sverige, empty cells do not imply zero value, but “data saknas” – missing data.

The most dramatic is the availability of data on recycling, both variables for per capita amount to recycling and the share of recycled waste have more than 80% of missing data. Other key variables also have almost half of the values missing on average.

## 8.2. Normality Tests and Pairwise Correlations

As many methods of analysis imply normality of distribution as a requirement, it is important to have normality checks for variables that are to be incorporated into further analysis. Large sample size might make numeric tests for normality too sensitive, therefore graphical tests were utilized. Normal Q-Q plots (based on expected normal value and observed value) were provided by SPSS for all the 15 variables, and visual analysis proved that 15 variables can be regarded as normally distributed, as data points resemble diagonal lines.

Also, both for possible building regression models at the next stage of the analysis, and purely for the goal of investigation of dependencies, correlation analysis is performed. As the level of measurement is ratio, Pearson correlation was calculated for all possible pairs of the following 15 variables:

The figure with significant correlation coefficients highlighted is presented below. Correlations marked with * are significant at the level of 0.05 for 2-tailed distribution, and correlations marked with ** are significant at the level of 0.01 for 2-tailed distribution.
Fig. 6 Pearson correlation coefficients between the variables

<table>
<thead>
<tr>
<th></th>
<th>CW_HouseholdSimilar</th>
<th>CW_Bio_Bags</th>
<th>CW_Bulk</th>
<th>CW_PackagingNewspapers</th>
<th>HW_Incineration</th>
<th>HW_Biotreatment</th>
<th>HW_Recycling</th>
<th>Percent_Biotreatment</th>
<th>Landfill</th>
<th>Pop</th>
<th>Age</th>
<th>Density</th>
<th>Area</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW_HouseholdSimilar</td>
<td>1</td>
<td>.094**</td>
<td>.931**</td>
<td>.080**</td>
<td>.113**</td>
<td>.011</td>
<td>.260**</td>
<td>.007</td>
<td>.094</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CW_Bio_Bags</td>
<td>.094**</td>
<td>1</td>
<td>-0.011</td>
<td>0.033</td>
<td>.061**</td>
<td>.101**</td>
<td>.189**</td>
<td>.003</td>
<td>.114**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CW_Bulk</td>
<td>.931**</td>
<td>-0.011</td>
<td>1</td>
<td>0.033</td>
<td>.061**</td>
<td>.101**</td>
<td>.189**</td>
<td>.003</td>
<td>.114**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CW_PackagingNewspapers</td>
<td>.080**</td>
<td>.101**</td>
<td>.033</td>
<td>1</td>
<td>.061**</td>
<td>.101**</td>
<td>.189**</td>
<td>.003</td>
<td>.114**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW_Incineration</td>
<td>.113**</td>
<td>.061**</td>
<td>.033</td>
<td>1</td>
<td>-.209**</td>
<td>.367**</td>
<td>-.495**</td>
<td>.416**</td>
<td>.085</td>
<td>.073</td>
<td>-.05</td>
<td>-.04</td>
<td>.011</td>
<td>-.096</td>
</tr>
<tr>
<td>HW_Biotreatment</td>
<td>.011</td>
<td>.267**</td>
<td>.007</td>
<td>.047</td>
<td>-.086</td>
<td>.045</td>
<td>.028</td>
<td>-.02</td>
<td>-.013</td>
<td>-.162</td>
<td>.106</td>
<td>.046</td>
<td></td>
<td>.051</td>
</tr>
<tr>
<td>HW_Recycling</td>
<td>.094**</td>
<td>.187**</td>
<td>.251**</td>
<td>.047</td>
<td>.047</td>
<td>1</td>
<td>.009</td>
<td>.141</td>
<td>-.042</td>
<td>.127</td>
<td>-.046</td>
<td>-.039</td>
<td>-.096</td>
<td></td>
</tr>
<tr>
<td>Percent_Biotreatment</td>
<td>-.096</td>
<td>-.495**</td>
<td>-.047</td>
<td>1</td>
<td>-.009</td>
<td>.141</td>
<td>.009</td>
<td>.141</td>
<td>-.351**</td>
<td>.589</td>
<td>-.072</td>
<td>-.052</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procent_HW_Recycling</td>
<td>.085**</td>
<td>-.651**</td>
<td>.047</td>
<td>1</td>
<td>-.009</td>
<td>.141</td>
<td>.009</td>
<td>.141</td>
<td>-.351**</td>
<td>.589</td>
<td>-.072</td>
<td>-.052</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landfill</td>
<td>-.027</td>
<td>-.015</td>
<td>-.037</td>
<td>-.004</td>
<td>.037</td>
<td>.074</td>
<td>.037</td>
<td>.074</td>
<td>.037</td>
<td>.074</td>
<td>.074</td>
<td>.074</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pop</td>
<td>.013</td>
<td>.044</td>
<td>.016</td>
<td>.043</td>
<td>.106**</td>
<td>-.073</td>
<td>-.051</td>
<td>-.206**</td>
<td>-.096</td>
<td>.118</td>
<td>.092</td>
<td>-.548**</td>
<td>-.316</td>
<td>-.168</td>
</tr>
<tr>
<td>Age</td>
<td>-.016</td>
<td>-.054</td>
<td>.121**</td>
<td>.037</td>
<td>-.004</td>
<td>.037</td>
<td>.074</td>
<td>.037</td>
<td>.037</td>
<td>.037</td>
<td>.037</td>
<td>.037</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>-.006</td>
<td>-.021</td>
<td>-.012</td>
<td>.02</td>
<td>.121**</td>
<td>-.011</td>
<td>-.011</td>
<td>-.011</td>
<td>.011</td>
<td>.011</td>
<td>.011</td>
<td>.011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>-.004</td>
<td>-.002</td>
<td>-.015</td>
<td>.141**</td>
<td>-.044</td>
<td>.141</td>
<td>.141</td>
<td>.141</td>
<td>.141</td>
<td>.141</td>
<td>.141</td>
<td>.141</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>.013</td>
<td>.044</td>
<td>.016</td>
<td>.043</td>
<td>.106**</td>
<td>-.073</td>
<td>-.051</td>
<td>-.206**</td>
<td>-.096</td>
<td>.118</td>
<td>.092</td>
<td>-.548**</td>
<td>-.316</td>
<td>-.168</td>
</tr>
</tbody>
</table>

Generally, there are several significant correlations between parameters; however, the important question also concerns the strengths of these correlations. Significant correlations are highlighted in gray in Fig. 6. We can see that the variables have quite a lot of correlations between them, and some are perfectly understandable (as if one parameter is based on another, like percentage of recycling is based on the amount of recycling, for example), while some are less expected.

In order to analyze and decide, which correlations can actually have negative effect on regression models to build, the strengths of correlation coefficients was scrutinized and presented graphically in Fig. 7. Graphically strong correlations (Pearson’s coefficient is more than 0.5 or less than -0.5) have thinker lines, than the correlations with Pearson coefficient between -0.5 and -0.2 and 0.2 and 0.5.

Fig. 7 Visual scheme of significant and relatively strong correlations
The main problem for future regression models emerging from correlation analysis is deep interconnectedness of socio-economic factors, as well as several strong correlations between waste-related parameters. The solution proposed is to cut the variables which create strong significant correlations with other independent variables out of the model. For example, high correlation between “Amount of household waste for recycling” and “Percentage of household waste that is recovered through recycling” is explained by the logical dependency of one of them on another, and therefore only one of them is sufficient for the model, the “Amount of household waste for recycling”.

Situation is the same for the “Amount of household waste to central biological treatment” and “Percentage of food waste from “big kitchens” which is recycled by biological treatment”, and therefore only the “Amount of household waste to central biological treatment” would be included in the model. The other pairs of waste-related variables having strong significant correlations are “Amount of collected bulky waste” and “Amount of collected household waste and similar to household waste”, and of these two of course the key parameter of “Amount of collected household waste and similar to household waste” deserves to be included into model. Similarly, in the pair of “Amount of collected waste in bins and bags” and “Amount of household waste for incineration” the latter gets to be in the model.

Correlations between socio-economic parameters have two dangerously strong correlated pair, they are “Population size” and “Population density” (which is definitely no surprise) and “Mean age” with “Median income” (which is understandable, however not particularly expected). Based on the previous research, “population density” presumably has more explanatory power than just “population size”, and “income” is also more important than “age” based on previous studies. This reasoning stands under the choice of variables for future regression models.

Of 15 initial variables, 6 are to be excluded because of high correlations with other predictors – 4 on waste and 2 from socio-economic parameters:

- Percentage of household waste that is recovered through recycling
- Percentage of food waste from “big kitchens” which is recycled by biological treatment
- Amount of collected bulky waste
- Amount of collected waste in bins and bags
- Population size
- Mean age

Such logic is also based on the idea of which variables are the key ones for research design, and which are secondary and additional. Primary parameters are per capita amounts of waste at different stages of waste hierarchy, while secondary parameters include information on types of waste and shares of waste on the stage of recycling. The following table presents key variables highlighted in gray colour:

**Tab. 3 Key and secondary variables for analysis and modelling**

<table>
<thead>
<tr>
<th>Group</th>
<th>Name of variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste generation</td>
<td>Amount of collected household waste and similar to household waste (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of collected waste in bins and bags (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of collected bulky waste (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of collected packaging and newspaper material (kg/person)</td>
</tr>
<tr>
<td>Socio-economic factors of</td>
<td>Income (median disposable income of people between 20 and 64 years old),</td>
</tr>
<tr>
<td>waste generation</td>
<td>prisbasbelopp</td>
</tr>
<tr>
<td></td>
<td>Age (mean age by year of birth), years</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Population size, persons</td>
<td></td>
</tr>
<tr>
<td>Area, km²</td>
<td></td>
</tr>
<tr>
<td>Population density, inhabitants per km²</td>
<td></td>
</tr>
<tr>
<td><strong>Recycling</strong></td>
<td>Amount of household waste for recycling (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Percentage of food waste from “big kitchens” which is recycled by biological treatment (%)</td>
</tr>
<tr>
<td></td>
<td>Percentage of household waste that is recovered through recycling, including biological treatment (%)</td>
</tr>
<tr>
<td><strong>Recovery</strong></td>
<td>Amount of household waste for incineration (kg/person)</td>
</tr>
<tr>
<td></td>
<td>Amount of household waste to central biological treatment (kg/person)</td>
</tr>
<tr>
<td><strong>Landfill</strong></td>
<td>Amount from landfill residues from households (kg/person)</td>
</tr>
</tbody>
</table>

However, putting aside the analysis of correlations just for the sake of checking for multicollinearity for possible regression models to build, there is a need to interpret the correlations itself.

The surprising finding is the absence of strong correlations between the variables from socio-economic and waste-related groups, as most of the pairs with relatively strong correlations are pairs of variables within one and the same group. In spite of Fig. 6 showing some significant correlations between variables from waste-related block with socio-economic parameters, they are relatively weak, except for the only one represented in the visual scheme – between income and percentage of food waste from “big kitchens”, which goes to biological treatment (-0.200). This coefficient means, that the bigger is median income in the municipality, the less waste from “big kitchens” is sent to biological treatment. However, remembering about the amount of missing values for the variable of “percentage of waste that goes to biological treatment” (85%), this result is not built on a high amount of observations. We can conclude that there are no important relations between socio-economic and waste-related parameters, when it comes to Swedish municipalities.

However, there are some significant pairs of correlated parameters within these two groups. The group of waste-related variables presents interest. For example, the amount of collected household waste has high correlation with the amount of bulky waste, which probably indicates to a high share of bulky waste in overall waste generation. An interesting finding also is that the amount of waste to incineration has very high correlation with the amount of collected waste in bins and bags, and this fact is probably connected with the waste collection system, as when waste is collected in bins and bags, a huge share of it, which is not optically sorted, goes to incineration with energy recovery.

The amount of waste sent to landfill, despite our aim to find its correlations with other waste minimization steps to make conclusions about the most important stages of waste management, does not have any strong correlations. The correlation table (Fig. 6) shows, that it has significant correlations with the amount of collected packaging and newspaper waste (-0.112), the amount of household waste to recycling (0.159), population size (-0.088) and income (0.118), however these values of correlation coefficients are too small to be a ground for solid conclusions.

The additional analysis of correlation table (Fig. 6) in order to find at least weak significant correlations between socio-economic parameters and key waste-related variables (such as, besides discussed landfill, also the amount of collected waste, and the amount of waste to recycling), did not bring any result. The differences in waste management performance of municipalities seem to be explained by other factors than socio-economic.

Taking into consideration low amount of strong correlations between two groups of variables, possible regression models might show poor explanatory power, however in order to verify
whether the structure and causality between variables is present, regression models are built further in the paper, and their quality is assessed.

8.3. Missing values analysis

Twenty municipalities were cut out of the analysis because of their absence from AvfallWeb database. They were assessed and defined as random and not having common traits in aspects of socio-economic or waste management parameters, therefore there is no reason to imply they might have created bias.

There also might be a need of excluding a list of other cases (municipalities) from the analysis, as for waste minimization group of variables, the crucial requirement for modeling is the availability of data on amounts of waste per capita that are collected, recycled, recovered and landfilled, as there is no procedure to impute these values instead. However, the recycling variables (both of them, the amount of recycled waste and the percentage of recycled waste at “big kitchens”), have more than 80% of missing data, which sets the question of cutting recycling out of consideration at all.

To check whether numerous cases, which lack important data on waste collection, recycling, recovery, biological treatment and landfill, are different from the cases which have this information present, analysis of variance (ANOVA) is to be performed. To organize different groups of cases by the criteria of data presence in the same database, “dummy variables” were introduced. Dummy variables are qualitative variables, which assume the value 1 when the category they accompany is present, and 0 in case the category is absent (so they are binary variables which serve perfect for analysis of missing values.)

1. The data on waste collection and landfill amounts are missing.

The variables of waste collection and landfill are planned to be dependent variables in regression models to be built (one of them was planned as dependent on socio-economic variables, and the other – dependent on waste-related variables). Therefore there is no chance to incorporate cases with missing data on waste collection and landfill per capita into further analysis. New dummy variable “collection_and_landfill_A” has a value of 1 when both the amounts of waste collected and landfilled per capita are present (i.e. when variables “Amount of collected household waste (waste from households and similar waste from other activities) (kg/person)” and “Amount of landfill residues from households (kg/person)” have valid data for a case), and 0 otherwise.

In the database of 1080 cases, only 496 cases have this information and therefore the value of “collection_and_landfill_A” for each of them is 1. The first ANOVA is devoted to verification whether there are significant differences in the mean values for key parameters between two groups of cases depending on a value of the dummy variable ”collection_and_landfill_A”. The null hypothesis is that there are no differences between groups. If the null hypothesis is rejected, the alternate hypothesis is that there is significant difference between mean values of groups.

The assumptions for ANOVA are:
1. Independent variable forms two or more independent groups.
2. Normal distribution of dependent variables for each group formed by the independent variable.
3. Interval or ratio level of measurement for dependent variables.
4. Homogeneity of variances of dependent variables between independent groups (Levene’s Test).

For ANOVA based on grouping dummy variable “collection_and_landfill_A” and the key socio-economic and waste-related parameters (except for collection and landfill, of course), assumptions 1 and 3 are fulfilled by default. Assumptions 2 and 4 have to be checked for fulfillment first. Graphical tests for normality (normal Q-Q plots) showed that assumption 2 is fulfilled, too. Testing for homogeneity of variances is incorporated into SPSS ANOVA algorithm:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population (person)</td>
<td>23,901</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>20,261</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Population density (inhabitants per km²)</td>
<td>69,574</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>25,772</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Amount of household waste for incineration (kg/person)</td>
<td>3,980</td>
<td>1</td>
<td>587</td>
<td>.046</td>
</tr>
<tr>
<td>Amount of household waste to central biological treatment (kg/person)</td>
<td>3,551</td>
<td>1</td>
<td>560</td>
<td>.060</td>
</tr>
<tr>
<td>Amount of household waste for recycling (kg/person)</td>
<td>.920</td>
<td>1</td>
<td>204</td>
<td>.339</td>
</tr>
<tr>
<td>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</td>
<td>20,925</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
</tbody>
</table>

The groups have homogeneity of variances only if significance of Levene statistic is more than 0.05. Therefore, we can infer that only the two variables highlighted in bold have homogeneous variances and have valid ANOVA results:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of household waste to central biological treatment (kg/person)</td>
<td>8238,388</td>
<td>1</td>
<td>8238,388</td>
<td>3.217</td>
<td>.073</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1434302,716</td>
<td>560</td>
<td>2561,255</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1442541,104</td>
<td>561</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of household waste for recycling (kg/person)</td>
<td>935396,103</td>
<td>1</td>
<td>935396,103</td>
<td>.278</td>
<td>.599</td>
</tr>
<tr>
<td>Within Groups</td>
<td>687260609,455</td>
<td>204</td>
<td>3368924,556</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>688196005,558</td>
<td>205</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Both p-values (significance levels) are higher than 0.05, and therefore we accept the null hypothesis about absence of differences of means between groups for each of the variables. For other 6 variables, which proved to have different variances in groups and therefore cannot be part of ANOVA, Welch test was employed, which is designed for unequal variances:
**Tab 6 Robust Tests of Equality of Means**

<table>
<thead>
<tr>
<th>Statistic(a)</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population (person)</td>
<td>Welch</td>
<td>19,301</td>
<td>1</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>Welch</td>
<td>33,723</td>
<td>1</td>
</tr>
<tr>
<td>Population density (inhabitants per km(^2))</td>
<td>Welch</td>
<td>20,497</td>
<td>1</td>
</tr>
<tr>
<td>Area (km(^2))</td>
<td>Welch</td>
<td>8,042</td>
<td>1</td>
</tr>
<tr>
<td>Amount of household waste for incineration (kg/person)</td>
<td>Welch</td>
<td>0,037</td>
<td>1</td>
</tr>
<tr>
<td>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</td>
<td>Welch</td>
<td>11,998</td>
<td>1</td>
</tr>
</tbody>
</table>

If p-value is less than 0.05, then there are statistically significant differences between groups. In our case, we can infer that means between groups are different for 5 variables – average population size, mean age of population, population density, area, and median income, i.e. **all socio-economic parameters have different means depending on whether municipality has data on the most basic waste-management parameters: waste collection and landfill.**

The differences are presented in the table below:

**Tab 7 Report**

<table>
<thead>
<tr>
<th>collection_and_landfill_A</th>
<th>Average population (person)</th>
<th>Mean age of population (years)</th>
<th>Population density (inhabitants per km(^2))</th>
<th>Area (km(^2))</th>
<th>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>,00 (missing data on waste collection and landfill)</td>
<td>Mean</td>
<td>24301,545</td>
<td>43,1110</td>
<td>76,8420</td>
<td>1666,09 32</td>
</tr>
<tr>
<td>1,00 (present data on waste collection and landfill)</td>
<td>Mean</td>
<td>42487,935</td>
<td>42,2218</td>
<td>214,6095</td>
<td>1246,13 02</td>
</tr>
<tr>
<td>Total</td>
<td>Mean</td>
<td>32653,813</td>
<td>42,7026</td>
<td>140,1130</td>
<td>1473,22 13</td>
</tr>
</tbody>
</table>

Even though the differences are statistically significant, it needs to be noted that substantially they are not contrasting. In those municipalities, which submitted data on waste collection and landfill, the population is higher than general average population of a municipality in Sweden, and in those municipalities which didn’t submit data on collection and landfill of waste, the population is lower than general average population of a municipality in Sweden. Also, municipalities from the group with present data, have significantly higher population density, than average, while those from the group with missing data have lower population density than average. The group with present data is also a little bit “younger” and “richer” than average, while the other group has lower than average mean values for these variables of mean age and median income. Municipalities from the group with missing data have also bigger mean area, which probably indicates for a large share of northern municipalities among them.

Therefore, the most important differences between two groups formed upon the presence of waste collection and landfill data, are population size and population density. It might be useful to keep in mind income differences, too, however they are not drastic.
Nonetheless, the described differences between these groups would create a bias if we select only the group of cases with present data for building a regression model. In case this bias is impossible to avoid, it should be at least accounted for at the stage of interpretation of results.

2. The data on recycling are missing.

According to the table with missing data shares for each variable, the situation with missing values is clearly the worst for recycling-related variables. Figuring out the differences between more than 80% of cases with missing data on recycling and the remaining one fifth with this information present, is a task of very high priority. The scheme of the analysis is exactly the same as in the previous subchapter, i.e. based on dummy variable. The variable introduced to indicate the presence of values of “Amount of household waste for recycling (kg/person)” was named “recycling_A”. Only 206 cases have data on amount of per capita household waste for recycling, and therefore the value of “recycling_A” for them is 1. All the other cases get 0. Based on “recycling_A” as a grouping variable, ANOVA is to be performed. According to visual analysis of Q-Q plots, normality of distributions still can be assumed. Requirements of at least two groups and ratio level of measurement are fulfilled by default.

Three tables, representing Tests of Homogeneity of Variances, Analysis of Variances and Robust Tests of Equality of Means, along with the complete description of analytical procedure (same as performed above) can be found in Appendix.

ANOVA and Tests of Equality of Means suggest that six variables differ depending on the value of dummy variable: Population size, Mean age, Population density, Median income, Amount of waste for biological treatment, and Amount of household waste for incineration. The substantial differences are illustrated by the following table:

<table>
<thead>
<tr>
<th>recycling_A</th>
<th>Average population (person)</th>
<th>Mean age of population (years)</th>
<th>Population density (inhabitants per km²)</th>
<th>Median value for income of disposal of people between 20 and 64 years old (prisbasbelop p)</th>
<th>Amount of household waste for incineration (kg/person)</th>
<th>Amount of household waste to central biological treatment (kg/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 (missing data on recycling) Mean 27759.822 42,8364 105,7754 4,9008 272,9749 46,0192</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00 (present data on recycling) Mean 53417.643 42,1350 285,7976 5,0612 287,9053 36,5502</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Mean 32653.813 42,7026 140,1130 4,9314 277,7912 43,0201</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The trend for socio-economic parameters seems to be the same, as with the previous case of availability of data on waste collection and landfill as a grouping criterion. Municipalities with missing data have much lower means for population size and density (differences in population
density are especially huge, only 106 persons per km² on average in municipalities with missing data compared to 286 persons per km² in municipalities with present data), and lower income. When it comes to waste-related parameters, municipalities which didn’t submit data on recycling also tend to have less waste for incineration and remarkably more waste for biological treatment (46 kg per person compared to 36 kg per person on average in municipalities with present data on recycling). The main conclusion is that the municipalities which did provide valid data on recycling of waste (they are only about one-fifth of all cases), have differences in mean values from the whole sample and from those which didn’t provide data on recycling. Cases with missing data on recycling are characterized by lower population size and density, lower income, and simultaneously by higher amount of waste to biological treatment and lower waste to incineration – that may be considered as slightly better waste management situation.

If for the regression models cases with absent data on recycling are filtered out, then the sample for regression would be biased towards less populated municipalities with bigger amount per capita of waste to biological treatment and lower amount per capita of waste to incineration, i.e. municipalities with rather good waste management performance.

3. The data on waste incineration and biological treatment are missing.

Compared to the share of missing data on recycling, the share of missing data on biological treatment and waste incineration is relatively low, only 48% and 45.5% respectively. Also, the presence of the data on biological treatment and incineration is not as crucial as the presence of data on collection and landfill amounts when building a possible exploratory regression model, as these parameters are presumably just independent predictors, but not dependent variables. However the question about the difference between those cases which do have data on the amounts of waste treated by incineration or biological treatment, and those which don’t, still presents interest.

Therefore, the same operation of grouping all the cases by a criterion of data presence is employed. The new grouping variable is called “incineration_and_biotreatment_A”, and 520 cases have value of 1, meaning the presence of both values for incineration and for biotreatment (all the rest have value 0 for “incineration_and_biotreatment_A”, meaning that at least one of these values is missing). Graphical normality tests provide normal Q-Q plots for each of variables in each of groups, and analysis shows that the distributions may be considered and treated as normal.

The tables for Tests of Homogeneity of Variances, ANOVA, and Robust Tests of Equality of Means, are provided in Appendix with comments. The significant differences found between two groups depending on dummy variable value are the following:

<table>
<thead>
<tr>
<th>incineration_and_biotreatment_A</th>
<th>Average population (person)</th>
<th>Mean age of population (years)</th>
<th>Population density (inhabitants per km²)</th>
<th>Area (km²)</th>
<th>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>Mean</td>
<td>22675.040</td>
<td>43.1757</td>
<td>72.3571</td>
<td>1679.0050</td>
</tr>
</tbody>
</table>
From the report on means we can see, that the trend described previously for the differences between groups with and without certain values is present again – the cases from the group with missing data have lower mean values for population size, population density and income, while their area is bigger on average as well as the mean age is higher.

Excluding cases with missing data on waste incineration and biological treatment would also create bias towards more populated and a little bit "richer" and “younger” municipalities in regression models.

4. Differences between sample with all the key parameters present and the database with all kinds of missing values.

The last comparative analysis of groups with and without certain data relates to the situation of maximal filtering out missing values. Therefore the dummy variable introduced to assist the analysis has value 1 when all the five basic waste-related parameters have valid values, and 0 if at least one of them is missing. The variable's name is “all_A”, and its value is 1 in only 158 cases of 1080. Such low share of cases with full information is an indicator for general data quality. It also means that in case we decide to reduce the database to get rid of all cases with missing values, the variance of each predictor would significantly decrease, which would undermine the quality of the model. However, it is still an option to consider, as bias cannot be avoided when building possible regression models on the current database.

According to visual analysis of normal Q-Q plots, normality of distribution of variables under consideration in each group can be asserted. The three analytical tables can be found in Appendix. Welch test suggests that 5 variables have differences in means of two groups, and the differences are in average population size, mean age of population, population density, median income, and waste to central biological treatment.

<table>
<thead>
<tr>
<th></th>
<th>Median value for income for disposal of people between 20 and 64 years old (prisbasbelop p)</th>
<th>Average population (person)</th>
<th>Mean age of population (years)</th>
<th>Population density (inhabitants per km²)</th>
<th>Amount of household waste to central biological treatment (kg/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>all_A</td>
<td>Mean 4,9120</td>
<td>28386,567</td>
<td>42,8053</td>
<td>109,9614</td>
<td>46,4098</td>
</tr>
<tr>
<td>0,00</td>
<td>Mean 5,0443</td>
<td>57555,085</td>
<td>42,1032</td>
<td>316,0608</td>
<td>34,3529</td>
</tr>
<tr>
<td>1,00</td>
<td>Mean 4,9314</td>
<td>32653,813</td>
<td>42,7026</td>
<td>140,1130</td>
<td>43,0201</td>
</tr>
<tr>
<td>Total</td>
<td>Mean 4,9314</td>
<td>32653,813</td>
<td>42,7026</td>
<td>140,1130</td>
<td>43,0201</td>
</tr>
</tbody>
</table>

From analysis of means we can infer, that on average in municipalities where all the waste-related data is present, median income tends to be higher than in the municipalities with missing data, as well as the population is significantly higher and a lot more dense. However these municipalities have less waste sent to central biological treatment (that might be explained by more dense population – most probably in the cities people are less involved in sorting biodegradable waste than in the regions with single-family houses on land.)
Generally, the analysis of cases which are characterized by missing values for waste-related variables, shows that they are significantly different from the whole population and the cases with the present data, mostly by their socio-economic parameters (such as population size, population density, area, age, and median income) and in some cases even by their waste management parameters (such as per capita waste to incineration and to biological treatment).

The main conclusion of this analysis is that any kind of reduction of cases from the database would necessarily create bias towards municipalities with non-average characteristics.

### 8.4. FULFILLMENT OF REQUIREMENTS AND ASSUMPTIONS FOR MULTIPLE REGRESSION MODELS

**Tab 11 Fulfillment of assumptions for the method of multiple regression**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Fulfillment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representative sample</td>
<td>Not fulfilled as missing data create bias. However the analysis would still be conducted, bias needs to be taken into account in the process of interpretation of results.</td>
</tr>
<tr>
<td>Interval or ratio scales by level of measurement of variables</td>
<td>Fulfilled</td>
</tr>
<tr>
<td>Variables are measured without error, or the measurement error is not significant and not systemic</td>
<td>Fulfilled, given the trust to data sources (as we rely on data collected externally, there is nothing to influence)</td>
</tr>
<tr>
<td>Absence of systemic error (error should be random and with a mean of zero instead)</td>
<td>Fulfilled</td>
</tr>
<tr>
<td>Absence of multicollinearity of independent variables</td>
<td>Fulfilled, given the analysis performed above and exclusion of mentioned variables from analysis</td>
</tr>
<tr>
<td>Homoscedasticity</td>
<td>Assumption made based on visual analysis of distributions</td>
</tr>
<tr>
<td>Relations between independent and dependent variables are linear</td>
<td>Assumption made, if non-linear, different method should be used</td>
</tr>
<tr>
<td>Causality and causal structure of the model are inherent</td>
<td>Assumption made based on previous research</td>
</tr>
</tbody>
</table>

### 8.5. METHOD FOR TREATING MISSING VALUES AND SAMPLE SIZE

In spite of the initial idea to include all cases and all proposed variables into regression models for exploration of structure of relations between parameters, the correlation analysis has reduced the list of variables (which is good, as mentioned above: the less dimensions – the better the clarity for a model), and also the analysis of missing values suggests that for more stable model some of the cases need to be excluded. However, a very important note is that having described the differences between missing data and present data, there is no way the assumption about
missing at random can be made. The bias created by excluding the cases with missing values is inevitable and has to be taken into consideration.

There are two approaches to reduction of the current database, which seem reasonable. First is trying to keep as many cases as possible by only excluding the cases with missing data on waste collection and waste landfill. Second is leaving only cases with all the five parameters present. Previous analysis of differences between means shows, that both these approaches would create bias by socio-economic parameters towards more populated municipalities with bigger income. Therefore all the cases which contain missing values are filtered out of the regression analysis; the remaining 158 cases are enough for a sample.

8.6. MODELLING

The results of correlation analysis showed that most probably the attempts to model causal structure for the set of variables which lacks strong correlations (besides ones that are explained directly) would not bring about a very good model, however several trials are needed to prove it. Hypothetically, according to previous research, possible dependent variables are the amount of collected waste (then socio-economic parameters may be independent variables), the amount of recycled waste (and then both waste-related and socio-economic parameters may be predictors), and the amount of landfilled waste (both waste-related and socio-economic parameters may be predictors). The three corresponding models are described in the current chapter. The tables with quantitative characteristics of the models are provided in the Appendix.

1. Model for explaining the variance of the amount of collected waste by socio-economic parameters

The model is described by the following characteristics: dependent variable: “Amount of collected household waste”; independent variables: “Median value for income”, “Population density”, “Area”.

For such model, the parameter of Adjusted $R^2$ suggests that only 4.4% of variance of dependent variable is explained by independent variables (income, population density and area). In spite of the fact that the model is actually significant, as well as the coefficient for “Area” (which suggests that area has high influence of the amount of collected household waste), the model is not acceptable to explain waste generation in Swedish municipalities.

2. Model for explaining the variance of the amount of recycled waste

The model is described by the following characteristics: dependent variable: “Amount of household waste for recycling”; independent variables: “Median value for income”, “Population density”, “Area”, “Amount of collected household waste”, “Amount of household waste to central biological treatment”, “Amount of landfill residues from households”, “Amount of collected packaging and newspaper material”, “Amount of household waste for incineration”.

Adjusted $R^2$ for model 2 is also not very high, only 18% of variance of “Amount of household waste for recycling” can be explained by the model. A model is considered to be of good quality and with fair explanatory power only if adjusted $R^2$ is more than 70%, at least 65%. Therefore, even though model 2 is better than model 1, it has low explanatory power and cannot be applied to Swedish municipalities (or, more precisely, the sample of them under consideration – biased
towards higher population size, density and income). Moreover, as the “Amount of household waste for recycling” revealed a lot of fairly high significant correlations, and only the strongest of them were taken out of the analysis, high values of model quality indicators might partially be explained by multicollinearity of predictors.

3. Model for explaining the variance of the amount of landfilled waste

The model is described by the following characteristics: dependent variable: “Amount of landfill residues from households”; independent variables: “Amount of household waste for recycling”, “Amount of household waste to central biological treatment”, “Amount of collected packaging and newspaper material”, “Amount of collected household waste”, “Amount of household waste for incineration”, “Median value for income”, “Population density”, “Area”.

Only 7.3% of variance is explained by the model, judging by adjusted R². However the model is significant, and the two significant predictors with relatively high coefficients are “Amount of collected household waste” and “Amount of collected packaging and newspaper material”. However, the model has a very low explanatory power, and therefore should be rejected.

Thus, as expected, multiple regression analysis provided weak models of low quality, and therefore the conclusions to the research are provided based on the correlation analysis, and the substantial results of missing values analysis.
9. CONCLUSION AND DISCUSSION

The explorative analysis of data was focused on three main issues – investigation into data quality, analysis of missing values, and correlation analysis.

The first subject to discuss is the results of the investigation into data quality. The standard procedure of data consistency and quality check revealed a serious problem with the missing data on waste-related parameters on municipal level. The amounts of missing values even for the most basic parameters were unexpectedly large, and distributed unevenly between variables and cases, as compared to expected share of missing values of about 10%, distributed evenly. This fact puts the quality of measurement techniques for waste amounts on each of the stages of municipal waste management under question. According to the results of the current research, the problem with waste-related data is the most significant in the sphere of recycling. An interesting question for research hence relates to improvements of measurement techniques for recycling of municipal solid waste. For the data on the national level, other units than municipalities might provide valid information – for example, branch organizations within EPR, or waste treatment plants. However the presence of data on municipal level is very important for monitoring and developing MSWM, and therefore it is highly recommended that stimulation of accurate data submission into database and increasing data quality become new tasks for MSWM in Sweden.

The second issue, which was mainly important due to abovementioned data quality, is the analysis of missing data, which had to be extensive because of a large amount of missing values. Within the analysis, interdependencies were discovered between some characteristics of municipalities and the type of data they don’t submit to the database. The general tendency for differences between municipalities depending on the presence of their data in the database, is that the municipalities which have missing values are on average less densely populated, have bigger area, smaller median income and tend to send more waste to biological treatment than average. Dealing with large amount of missing values in case they are not random requires either a dedication to continue working with biased data, or advanced modelling in order attribute new values to missing values based on possible structure of missing data. Within the current research, dealing with biased data was chosen, however the critical view on results shows that attributing new values to missing values might be an option for future research as it would keep the number of cases and variance higher than simple reduction of the database.

The third and main part of the analysis was the study of pairwise correlations (measured by Pearson’s coefficient) in order to find all the possible correlations between waste generation, waste minimization and socio-economic parameters. No strong and significant correlations were found between variables from different groups, waste-related and socio-economic. The strongest correlations were found within the group of waste-related parameters; however they are mostly explained by waste hierarchy implementation – such as correlation between per capita amounts of waste to biological treatment and to incineration. Analysis of weaker significant correlations showed that income and population density are socio-economic parameters which correlate with waste-related variables.

Multiple regression models were built as an attempt to reveal causality and structure between variables, and the models had low explanatory power, as expected. The one model having the best $R^2$ value (of three pretty weak models) was the one where “the amount of waste to recycle” was the dependent variable. Explaining the differences between the amounts of waste to recycle per capita in Swedish municipalities therefore might be a possible direction for future research. During future research, the quality of such experimental regression models might also
be improved in case different assumptions are made. Due to limitations of the scope and volume of the current study, it involved several assumptions, such as linearity of relations between variables and causality of structure. The quality of regression models which were built might be to some extent explained by the relevance of assumptions: there are likely non-linear relations between parameters, and the structure as well may not be characterized by causal relationships between variables, just the correlations, without causality. The complexity of relations between waste management performance and socio-economic characteristics of any social community (and a Swedish municipality as well) may call more complex, non-linear modelling.

Moreover, the parameters chosen for the analysis within the current research were not only based on the results of previous research in the field, but also on data availability. If the data on several other socio-economic parameters of those mentioned in the previous research were provided, new trial regression model would be possible to build. For example, the level of education would be one of possible parameters with positive explanatory power.

The general conclusion to main analytical part devoted to correlations and interdependencies is that as there are merely weak correlations between waste-related and basic socio-economic parameters, and therefore the differences in waste management performance of municipalities seem to be explained by other factors than basic socio-economic factors.

Hence, the most important direction for future research is based on the following question: if basic socio-economic parameters do not explain waste generation and waste minimization in Swedish municipalities so well, which parameters do? Waste management parameters in Swedish municipalities are not drastically different, as generally waste management is subject to strict regulations (as described in theoretical part of the current paper). Also, the society of Sweden is relatively homogeneous compared to other countries, and is characterized by equality. Therefore, the underlying reasons which explain the differences in waste amounts on every step of waste minimization in municipalities must be very local. Any future research aiming to find these reasons might consider more soft approach, and qualitative methodology, as possible explanations might be found within cultural or psychological factors, within something that affects action of households. It might be proximity of recycling stations, their cleanliness and design, the presence of any kind of psychological reward for sorting and recycling, or a good “neighbour” example. Also, the differences might be explained by practice of waste management companies in the region, and introduced local systems of waste collection. Possible local reasons are various; however all these potential factors require a combination of qualitative and quantitative research.

The main and most interesting conclusion of the current study is that the dependencies and correlations between waste generation, waste minimization and socio-economic parameters were found in a very different aspect than expected. Instead of waste generation and waste minimization being explained by waste-related variables and socio-economic parameters, it was proven that the availability of municipal data on waste amounts correlates with them. Rather than explaining differences between municipalities and variance of their waste-related parameters, socio-economic factors were connected with the differences between municipalities in aspect of their data availability.
10. APPENDIX


Waste - any substance or object which the holder discards or intends or is required to discard.
Bio-waste - biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.
Waste producer - anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.
Waste holder - the waste producer or the natural or legal person who is in possession of the waste.
Dealer - any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste.
Broker - any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste.
Waste management - the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker.
Collection - the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility.
Separate collection - the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment.
Prevention - measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products; (b) the adverse impacts of the generated waste on the environment and human health; or (c) the content of harmful substances in materials and products.
Re-use - any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.
Treatment - recovery or disposal operations, including preparation prior to recovery or disposal.
Recovery - any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations.
Repairing for re-use - checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.
Recycling - any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.
Disposal - any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I sets out a non-exhaustive list of disposal operations.

List of abbreviations
ANOVA – analysis of variances;
EPA – Environmental Protection Agency;
EPR – extended producer responsibility;
MSW – municipal solid waste;
MSWM – municipal solid waste management;
SCB – Statistiska Centralbyrån;
WEEE - waste electrical and electronic equipment.


DISPOSAL OPERATIONS
D 1 Deposit into or on to land (e.g. landfill, etc.)
D 2 Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
D 3 Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
D 4 Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)
D 5 Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
D 6 Release into a water body except seas/oceans
D 7 Release to seas/oceans including sea-bed insertion
D 8 Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12
D 9 Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)
D 10 Incineration on land
D 11 Incineration at sea (*)
D 12 Permanent storage (e.g. emplacement of containers in a mine, etc.)
D 13 Blending or mixing prior to submission to any of the operations numbered D 1 to D 12 (**)
D 14 Repackaging prior to submission to any of the operations numbered D 1 to D 13
D 15 Storage pending any of the operations numbered D 1 to D 14 (excluding temporary storage, pending collection, on the site where the waste is produced) (***)


RECOVERY OPERATIONS
R 1 Use principally as a fuel or other means to generate energy (*)
R 2 Solvent reclamation/regeneration
R 3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes) (**)
R 4 Recycling/reclamation of metals and metal compounds
R 5 Recycling/reclamation of other inorganic materials (***)
R 6 Regeneration of acids or bases
R 7 Recovery of components used for pollution abatement
R 8 Recovery of components from catalysts
R 9 Oil re-refining or other reuses of oil
R 10 Land treatment resulting in benefit to agriculture or ecological improvement
R 11 Use of waste obtained from any of the operations numbered R 1 to R 10
R 12 Exchange of waste for submission to any of the operations numbered R 1 to R 11 (****)
R 13 Storage of waste pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced) (*****)

EXAMPLES OF WASTE PREVENTION MEASURES REFERRED TO IN ARTICLE 29

Measures that can affect the framework conditions related to the generation of waste
1. The use of planning measures, or other economic instruments promoting the efficient use of resources.
2. The promotion of research and development into the area of achieving cleaner and less wasteful products and technologies and the dissemination and use of the results of such research and development.
3. The development of effective and meaningful indicators of the environmental pressures associated with the generation of waste aimed at contributing to the prevention of waste generation at all levels, from product comparisons at Community level through action by local authorities to national measures.

Measures that can affect the design and production and distribution phase
4. The promotion of eco-design (the systematic integration of environmental aspects into product design with the aim to improve the environmental performance of the product throughout its whole life cycle).
5. The provision of information on waste prevention techniques with a view to facilitating the implementation of best available techniques by industry.
6. Organise training of competent authorities as regards the insertion of waste prevention requirements in permits under this Directive and Directive 96/61/EC.
7. The inclusion of measures to prevent waste production at installations not falling under Directive 96/61/EC. Where appropriate, such measures could include waste prevention assessments or plans.
8. The use of awareness campaigns or the provision of financial, decision making or other support to businesses. Such measures are likely to be particularly effective where they are aimed at, and adapted to, small and medium sized enterprises and work through established business networks.
9. The use of voluntary agreements, consumer/producer panels or sectoral negotiations in order that the relevant businesses or industrial sectors set their own waste prevention plans or objectives or correct wasteful products or packaging.
10. The promotion of creditable environmental management systems, including EMAS and ISO 14001.

Measures that can affect the consumption and use phase
11. Economic instruments such as incentives for clean purchases or the institution of an obligatory payment by consumers for a given article or element of packaging that would otherwise be provided free of charge.
12. The use of awareness campaigns and information provision directed at the general public or a specific set of consumers.
14. Agreements with industry, such as the use of product panels such as those being carried out within the framework of Integrated Product Policies or with retailers on the availability of waste prevention information and products with a lower environmental impact.
15. In the context of public and corporate procurement, the integration of environmental and waste prevention criteria into calls for tenders and contracts, in line with the Handbook on environmental public procurement published by the Commission on 29 October 2004.
16. The promotion of the reuse and/or repair of appropriate discarded products or of their components, notably through the use of educational, economic, logistic or other measures such as support to or establishment of accredited repair and reuse-centres and networks especially in densely populated regions.
Supporting tables to 8.3 Analysis of missing values, point 2 – comparison of groups of cases depending on the availability of data on recycling

**Tab 12 Test of Homogeneity of Variances**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population (person)</td>
<td>44,048</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>11,385</td>
<td>1</td>
<td>1078</td>
<td>.001</td>
</tr>
<tr>
<td>Population density (inhabitants per km²)</td>
<td>72,317</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Area (km²)</strong></td>
<td><strong>2,195</strong></td>
<td>1</td>
<td>1078</td>
<td>.139</td>
</tr>
<tr>
<td>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</td>
<td>18,376</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Amount of collected household waste (waste from households and similar waste from other activities) (kg/person)</td>
<td>1,363</td>
<td>1</td>
<td>567</td>
<td>.243</td>
</tr>
<tr>
<td>Amount of household waste for incineration (kg/person)</td>
<td>.580</td>
<td>1</td>
<td>587</td>
<td>.447</td>
</tr>
<tr>
<td>Amount of household waste to central biological treatment (kg/person)</td>
<td>15,726</td>
<td>1</td>
<td>560</td>
<td>.000</td>
</tr>
<tr>
<td>Amount of landfill residues from households (kg/person)</td>
<td>.641</td>
<td>1</td>
<td>591</td>
<td>.424</td>
</tr>
</tbody>
</table>

Variances of two groups are homogeneous for the highlighted four variables; therefore ANOVA results are only valid for them.

**Tab 13 ANOVA**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area (km²)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>3488922,639</td>
<td>1</td>
<td>3488922,639</td>
<td>.543</td>
<td>.461</td>
</tr>
<tr>
<td>Within Groups</td>
<td>6927353600,533</td>
<td>1078</td>
<td>6426116,513</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6930842523,172</td>
<td>1079</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amount of collected household waste (waste from households and similar waste from other activities) (kg/person)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>13853,422</td>
<td>1</td>
<td>13853,422</td>
<td>.069</td>
<td>.793</td>
</tr>
<tr>
<td>Within Groups</td>
<td>114039104,810</td>
<td>567</td>
<td>201127,169</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Of these four variables, three have p-value higher than 0.05, which indicates the absence of differences of means between groups for each of them – Area, Amount of collected waste, and Amount of landfill residues. Low p-value of 0.038 indicates for the presence of differences between two groups in aspect of mean value for Amount of household waste for incineration.

For the five variables, which have different variances in groups (non-highlighted variables in the table with homogeneity test), Welch test is performed.

### Tab 14 Robust Tests of Equality of Means

<table>
<thead>
<tr>
<th>Variable</th>
<th>Statistic(a)</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population (person)</td>
<td>Welch</td>
<td>9,970</td>
<td>1</td>
<td>219,358</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>Welch</td>
<td>11,201</td>
<td>1</td>
<td>284,716</td>
</tr>
<tr>
<td>Population density (inhabitants per km$^2$)</td>
<td>Welch</td>
<td>10,607</td>
<td>1</td>
<td>226,326</td>
</tr>
<tr>
<td>Area (km$^2$)</td>
<td>Welch</td>
<td>7,730</td>
<td>1</td>
<td>378,830</td>
</tr>
<tr>
<td>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</td>
<td>Welch</td>
<td>20,781</td>
<td>1</td>
<td>260,285</td>
</tr>
<tr>
<td>Amount of collected household waste (waste from households and similar waste from other activities) (kg/person)</td>
<td>Welch</td>
<td>1,123</td>
<td>1</td>
<td>413,375</td>
</tr>
<tr>
<td>Amount of household waste for incineration (kg/person)</td>
<td>Welch</td>
<td>4,418</td>
<td>1</td>
<td>383,258</td>
</tr>
<tr>
<td>Amount of household waste to central biological treatment (kg/person)</td>
<td>Welch</td>
<td>5,965</td>
<td>1</td>
<td>517,990</td>
</tr>
<tr>
<td>Amount of landfill residues from households (kg/person)</td>
<td>Welch</td>
<td>2,674</td>
<td>1</td>
<td>342,440</td>
</tr>
</tbody>
</table>

Welch test suggests that all the variables we are evaluating have differences in means of two groups, as all p-values (significance levels) are less than 0.05. Previously ANOVA demonstrated that means in groups for Amount of household waste for incineration are also different (that is proven by Welch test, too). Therefore a report is needed to see and interpret differences between means for these six variables: Population size, Mean age, Population density, Median income, Amount of waste for biological treatment, and Amount of household waste for incineration.

Supporting tables to 8.3 Analysis of missing values, point 3 – comparison of groups of cases depending on the availability of data on incineration and biological treatment

### Tab 15 Test of Homogeneity of Variances
The Levene statistic is significant only for three variables, all of them waste-related (highlighted above). Therefore we can infer that only these three variables have same variances in groups and therefore valid results of ANOVA.

**Tab 16 ANOVA**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amount of collected</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>household waste</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(waste from households</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and similar waste from</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>other activities) (kg/person)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Between Groups</strong></td>
<td>247524,590</td>
<td>1</td>
<td>247524,590</td>
<td>1,23</td>
<td>.267</td>
</tr>
<tr>
<td><strong>Within Groups</strong></td>
<td>113805433,642</td>
<td>567</td>
<td>200715,051</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>114052958,232</td>
<td>568</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amount of household</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>waste for recycling</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(kg/person)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Between Groups</strong></td>
<td>1474934,807</td>
<td>1</td>
<td>1474934,807</td>
<td>.438</td>
<td>.509</td>
</tr>
<tr>
<td><strong>Within Groups</strong></td>
<td>686721070,752</td>
<td>204</td>
<td>3366279,759</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ANOVA shows that for these three variables p-levels are more than 0.05, i.e. differences of means between groups are unlikely, and therefore the groups of cases with and without data on incineration and biotreatment are quite similar when it comes to waste management parameters. For the rest five socio-economic variables, which have shown differences in variances and therefore were excluded from ANOVA interpretation, Welch test is performed:

**Tab 17 Robust Tests of Equality of Means**

<table>
<thead>
<tr>
<th></th>
<th>Statistic(a)</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population (person)</td>
<td>Welch</td>
<td>26,897</td>
<td>1</td>
<td>623,175</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>Welch</td>
<td>42,237</td>
<td>1</td>
<td>1031,825</td>
</tr>
<tr>
<td>Population density (inhabitants per km²)</td>
<td>Welch</td>
<td>23,128</td>
<td>1</td>
<td>677,716</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>Welch</td>
<td>7,979</td>
<td>1</td>
<td>938,497</td>
</tr>
<tr>
<td>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</td>
<td>Welch</td>
<td>12,269</td>
<td>1</td>
<td>1010,141</td>
</tr>
</tbody>
</table>

Welch test suggests that all the variables we are evaluating have differences in means of two groups, as all p-values (significance levels) are less than 0.05 – thus, cases with and without data on incineration and biotreatment have significantly different means of socio-economic parameters.

**Supporting tables to 8.3 Analysis of missing values, point 4 – comparison of groups of cases depending on the availability of data for all variables**

**Tab 18 Test of Homogeneity of Variances**

<table>
<thead>
<tr>
<th></th>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population (person)</td>
<td>49,415</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>11,553</td>
<td>1</td>
<td>1078</td>
<td>.001</td>
</tr>
<tr>
<td>Population density (inhabitants per km²)</td>
<td>80,767</td>
<td>1</td>
<td>1078</td>
<td>.000</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>4,100</td>
<td>1</td>
<td>1078</td>
<td>.043</td>
</tr>
</tbody>
</table>
### Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)

<table>
<thead>
<tr>
<th>Amount of collected household waste (waste from households and similar waste from other activities) (kg/person)</th>
<th>6,648</th>
<th>1</th>
<th>1078</th>
<th>.010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of household waste for incineration (kg/person)</td>
<td>1,096</td>
<td>1</td>
<td>567</td>
<td>.295</td>
</tr>
<tr>
<td>Amount of household waste to central biological treatment (kg/person)</td>
<td>16,462</td>
<td>1</td>
<td>560</td>
<td>.000</td>
</tr>
<tr>
<td>Amount of household waste for recycling (kg/person)</td>
<td>2,262</td>
<td>1</td>
<td>204</td>
<td>.134</td>
</tr>
<tr>
<td>Amount of landfill residues from households (kg/person)</td>
<td>.038</td>
<td>1</td>
<td>591</td>
<td>.845</td>
</tr>
</tbody>
</table>

The groups have homogeneity of variances only if significance of Levene statistic is more than 0.05. Therefore, we can infer that four variables highlighted in bold have homogeneous variances and have valid ANOVA results:

### Tab 19 ANOVA

<table>
<thead>
<tr>
<th>Amount of collected household waste (waste from households and similar waste from other activities) (kg/person)</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>809,581</td>
<td>1</td>
<td>809,581</td>
<td>.004</td>
<td>.949</td>
</tr>
<tr>
<td>Within Groups</td>
<td>114,052,148,651</td>
<td>567</td>
<td>201,150,174</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>114,052,958,232</td>
<td>568</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amount of household waste for incineration (kg/person)</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>193,054,416</td>
<td>1</td>
<td>193,054,416</td>
<td>2.896</td>
<td>.089</td>
</tr>
<tr>
<td>Within Groups</td>
<td>391,268,789</td>
<td>587</td>
<td>666,5,567</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>393,199,3,314</td>
<td>588</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amount of household waste for recycling (kg/person)</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>206,238,6,872</td>
<td>1</td>
<td>206,238,6,872</td>
<td>.613</td>
<td>.434</td>
</tr>
</tbody>
</table>
Of these four variables, all have p-value higher than 0.05, which indicates the absence of differences of means between groups for each of them – amount of collected household waste, amount of waste to incineration, amount of waste to recycling and amount of landfill residues. Welch test is employed to analyze the remaining variables with unequal variances:

**Tab 20 Robust Tests of Equality of Means**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Statistic(a)</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average population (person)</td>
<td>Welch</td>
<td>8,183</td>
<td>1</td>
<td>163,775</td>
</tr>
<tr>
<td>Mean age of population (years)</td>
<td>Welch</td>
<td>8,755</td>
<td>1</td>
<td>200,216</td>
</tr>
<tr>
<td>Population density (inhabitants per km²)</td>
<td>Welch</td>
<td>8,959</td>
<td>1</td>
<td>166,905</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>Welch</td>
<td>1,543</td>
<td>1</td>
<td>344,264</td>
</tr>
<tr>
<td>Median value for income for disposal of people between 20 and 64 years old (prisbasbelopp)</td>
<td>Welch</td>
<td>12,204</td>
<td>1</td>
<td>194,272</td>
</tr>
<tr>
<td>Amount of household waste to central biological treatment (kg/person)</td>
<td>Welch</td>
<td>9,751</td>
<td>1</td>
<td>462,477</td>
</tr>
</tbody>
</table>

Model summaries for 8.6 Modelling

1. Model for explaining the variance of the amount of collected waste by socio-economic parameters

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.249(a)</td>
<td>.062</td>
<td>.044</td>
</tr>
</tbody>
</table>

2. Model for explaining the variance of the amount of recycled waste

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.472(a)</td>
<td>.223</td>
<td>.181</td>
</tr>
</tbody>
</table>

3. Model for explaining the variance of the amount of landfilled waste
<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.347(a)</td>
<td>0.120</td>
<td>0.073</td>
</tr>
</tbody>
</table>
REFERENCES


59


