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IS WASTE SEPARATION WORTH IT? A MUNICIPALITY'S PERSPECTIVE

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IS WASTE SEPARATION WORTH IT? A MUNICIPALITY'S PERSPECTIVE

Vyplatí se obcím třídění komunálního odpadu?

Diploma Thesis

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Cíl práce, postup a použité metody:	Problémová oblast: Problémovou oblastí práce je odpadové hospodářství obcí, konkrétně nakládání s recyklovatelným komunálním odpadem – jeho třídění. V porovnání s běžným svozem odpadu bez jeho třídění to přináší obcím dodatečné náklady, které obce musí obvykle doplácet z vlastních rozpočtů. Otázkou pak je, jestli lze tyto dodatečné náklady vyvážit jejich tržními i netržními přínosy. Náklady obcí budou v práci porovnávány s možnými benefity třídění komunálního odpadu (preference obyvatel, netržní přínosy). Cíl práce: Cílem práce je porovnání kvantifikovaných netržních benefitů obyvatel s náklady obcí plynoucích z možnosti třídění komunálních odpadů. Struktura: 1. Úvod do problematiky způsobů nakládání s komunálním odpadem. 2. Přehled a srovnání s existující literaturou vztahující se ke zkoumanému tématu. 3. Sběr dat a jejich analýza. 4. Modelování situace na příkladu České republiky. 5. Interpretace zjištěných výsledků. 6. Zhodnocení, hlavní zjištění a závěry práce. Použité metody: Metody indukce, dedukce a syntézy získaných poznatků, analýza získaných dat s využitím ekonometrie.
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Annotation

This diploma thesis evaluates the waste separation in the context of municipal waste management. The aim is the overall assessment of the waste separation from the municipality's' perspective, extended by the closer examination of benefits from the waste separation and also identification and modeling of the indirect benefits. The general problematics of municipal waste separation is introduced, and the methods of evaluation are discussed in the first part of the thesis. The second part follows up with the modeling the situation in the case of the Czech Republic. The methods used for the purposes of analysis ware Cost-benefit analysis and the regression. The model of municipal indirect benefits was created within the contacted analysis. It was concluded, based on the findings in this thesis, that waste separation generates benefits for the municipalities that exceed the costs, hence it is worth to provide this service.

Anotace

Tato diplomová práce hodnotí třídění odpadů v kontextu odpadového hospodářství obcí. Cílem tedy bylo celkové zhodnocení třídění odpadů z pohledu obcí, rozšířené o bližší prozkoumání přínosů plynoucích z třídění odpadů a také identifikace a modelování netržních přínosů. V první, teoretické části je představena obecná problematika třídění odpadů v obcích, diskutovány tu jsou také metody oceňování. Druhá, praktická část navazuje modelováním situace v případě České republiky. Metodami použitými k analýze dat byly metoda nákladů a přínosů a regresní funkce. V rámci analýzy byl vytvořen model netržních přínosů pro obce z třídění odpadů. V závěru bylo zjištěno, že třídění odpadů generuje obcím určité přínosy, které převyšují jejich náklady, proto má cenu tuto službu nadále poskytovat svým občanům.

Keywords

Municipal Waste Management, Waste Separation, Non-market Valuation, Cost-benefit Analysis, Regression

Klíčová slova

Odpadové hospodářství obcí, třídění odpadů, mimotržní oceňování, Analýza nákladů a přínosů, regrese

Declaration

I hereby declare that I have developed and written this thesis “Is Waste Separation worth it? A municipality’s perspective.” independently, using only the sources listed in accordance with Czech legal regulations and the internal regulations of the Masaryk University and the faculty of Economics and administration.

In Brno, January 2019

Author’s signature

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INTRODUCTION

The waste management is an integral part of the municipality operation. For already several decades, the separation of waste emerges in importance as the emphasis is put on the sustainability. It has, however, one important drawback for the municipalities. Waste separation, in fact, generates additional costs to them compared to other ways of waste management (for example waste dumping) and in the same time only limited resources are associated with the municipal waste separation (Havel 2017) and the municipalities are thus forced to subsidize this service from other resources. This situation is nowhere near the solution since the obligation to separate the municipal waste is integrated in the Czech legislature and the objectives of both the European Union and the Czech Republic are to increase the proportion of separated waste even more in the future.

However, very little attention is paid to the benefits. We believe that there also exist some indirect benefits for the municipalities from the waste separation, although not easily observable. Therefore, we would like to examine the municipal benefits from waste separation in more detail and perhaps even add a new dimension to the evaluation of municipal waste separation by interconnecting the municipal benefits with citizens' preferences.

The aim of this thesis is, in the first place, evaluation of waste separation from the municipalities' point of view. We are further interested in the proportion of municipalities extra costs from waste separation and the indirect (i.e. unobserved) benefits that waste separation generates to the municipalities, in other words, whether are extra costs paid by municipalities adequate to benefits. For that purpose, we set another goal for us in this thesis: We also aim to identify and model the indirect benefits for the municipalities from the waste separation.

The structure of this thesis can be logically divided into two parts, the theoretical and the practical part. In the theoretical part, the problematics of waste separation in the context of municipalities and the theoretical background is outlined. The first two chapters then belong to this part. In the first chapter, the waste separation and its role in the municipal waste management is outlined. The specifics of the waste separation in the case of the Czech Republic also brought closer in this chapter. The following chapter then explores methods suitable for evaluation of municipal waste separation. The overview existing literature is provided, and the methods of evaluation and analysis are discussed.

The practical part then deals with the application of knowledge acquired in the previous part and illustrates the problematics with the concrete findings. The three other chapters are classified as practical part. Methods of data collection together with the description of the sampling method and obtained data are covered in the third chapter. In the fourth chapter, the data are analyzed by modeling the situation on the example of the Czech Republic. The methods used for that purpose are Cost-Benefit Analysis and the Regression Analysis. The basic interpretation is provided in this chapter as well. Lastly, in the fifth chapter, we discuss some problems that emerged throughout the thesis. In the conclusion of this thesis, we summarize the main results regarding the performance of municipal waste separation in the Czech Republic.

1 ROLE OF WASTE SEPARATION IN THE WASTE MANAGEMENT SYSTEMS

More and more emphasis is given on sustainable development in recent decades. From the idea of sustainability originate among others also the concept of the circular economy[1]. This concept of course, includes waste management. Appropriate waste treatment makes circular economy possible because even though in an ideal world there should be no actual waste generated, in reality, there always will be to some extent. The principle of circular economy is to find a way to return unwanted items (i.e. waste) back into economy/production process, or economic process, for example in the form of secondary materials or as energy.

Correct functioning of the circular economy in the waste management sector depends completely on waste sorting: separation of waste by materials serves as a first step leading into recycling. This is also the reason why waste separation is considered to be one of the key aspects of efficient and sustainable waste management. In accordance with the pursuit of the circular economy, the European Union and its member states (including the Czech Republic) committed to follow *waste management hierarchy* (*DIRECTIVE 2008/98/EC*) in the following order:

1) Prevention of waste generation
2) Re-use of waste
3) Waste recycling
4) Other recovery of waste (i.e. energy generation)
5) Waste removal (i.e. incineration, landfill)

As Malčeková and Šimek (2014) point out, first two points from this hierarchy do not exactly refer to the treatment of *existing waste*, because even re-use of waste makes waste stop being a waste, since the title *waste* refers to a thing for which we have no further use or purpose[2]. In the context of actual waste-treatment, we currently consider waste recycling as the most desirable method according to *WM hierarchy*.

The legislation of the European Union further sets specific goals with the purpose of encouraging recycling of municipal waste, which member states should adopt. For example, by 2030 should member states recycle 65% of municipal waste and reduce landfill to a maximum of 10% of municipal waste while forbidding landfill of separately collected waste and promoting of economic instruments to discourage landfilling (*COUNCIL DIRECTIVE 1999/31/ES*). To evaluate these specific goals is not the purpose of this thesis[3], it is rather considered as fact which is pressuring municipalities to promote waste separation systems at their area.

[1] For more detail of this concept se for example EC (2015)

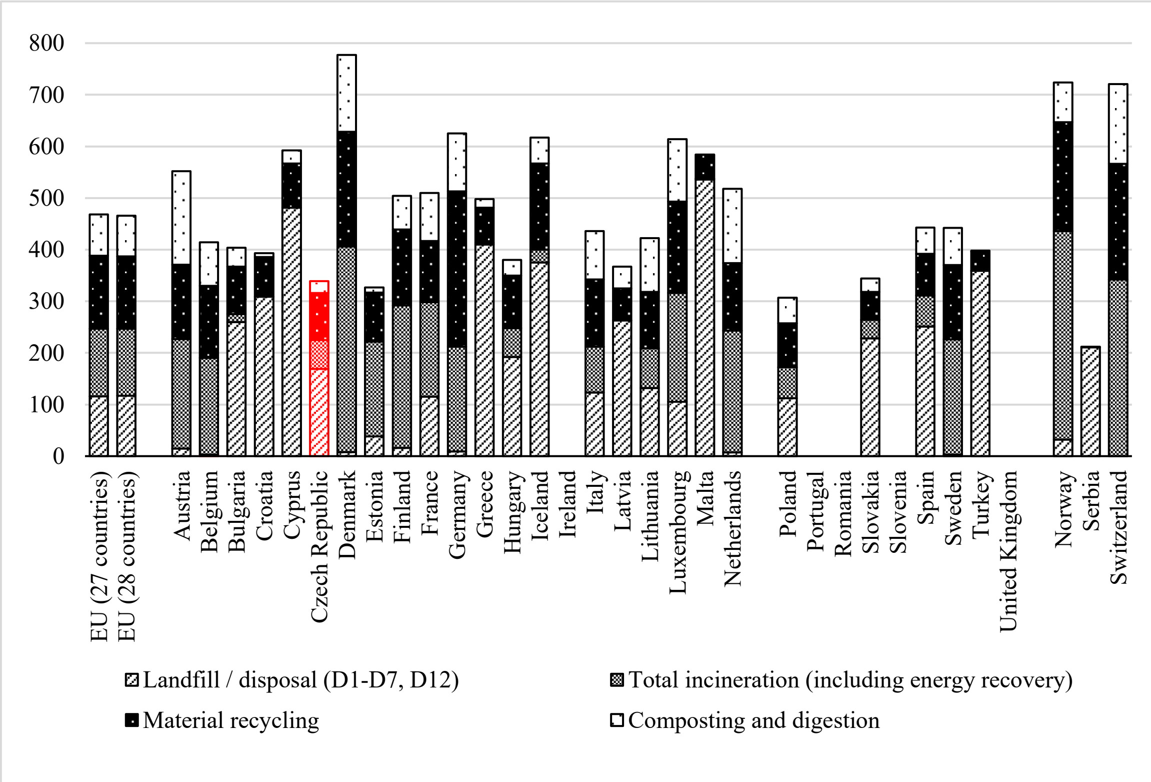
[2] According to Waste act No. 185/2001 Coll., Section 3, Subsection 1, waste is *"any movable thing the person discards or intends or is required to discard"*.

[3] It is, however, worth to at least mention, that some authors consider these goals cost-inefficient, unreasonable or even impossible to achieve (e.g. Pearce 2004; Hřebíček and Soukopová 2017), and in this context they are rather result of political decision.

It is also a fact that the most common treatment of the municipal waste is currently in the case of the Czech Republic landfilling. Over half of the municipal waste ends up in landfills. In the comparison among EU countries (see Figure 1), the Czech Republic fall over average in this landfill (even though in the case of total municipal waste production, The Czech Republic currently belongs to those who produce the least amount of municipal waste, according to available statistics). On the other hand, the contribution to material recycling is currently far from achieving the set targets.

FIGURE 1

MUNICIPAL WASTE GENERATION AND TREATMENT, BY TYPE OF TREATMENT METHOD (KG PER CAPITA)



Source: Eurostat (2017a)

Targets of the Czech Republic as listed in the Waste Management Plan (MoE 2014) correspond with targets of EU. Apart from the commitment to comply to waste management hierarchy, The Czech Republic also committed to achieving at least 50 % of the weight of municipal waste to be separated (i.e. prepared for re-use and recycling). The obligatory collection of separated waste fractions such as paper, plastic, glass and metal materials, is also mentioned, and it was introduced already in 2001 (*Waste Act, §17(3)*).

In the actual situation the Czech Republic is able to utilize materially (i.e. separate and recycle) 37,53 % of municipal waste (MoE 2018). This makes even more pressure on municipalities to separate waste since the responsibility about municipal waste separation lies on them. Municipalities then have to commit to intensive waste separation, even though it is not a very profitable activity to them (more about this in coming chapters).

1.1 DEFINITION OF SEPARATED MUNICIPAL WASTE

Since the primary focus of this thesis should be on municipalities, we should define what is the municipal waste, first. Municipal waste is by its characteristics waste from consumption[4]. Such waste is generated during consumption or typically after it: at the end of its product life. Apart from municipal waste, also e.g. electronic waste, car wracks, medical waste and transport waste (such as tires and waste oils) are considered as waste from consumption (Kuraš and Dirner 2005).

OECD defines municipal waste as *"waste collected and treated by or for municipalities"* (OECD 2017). A similar definition is also offered by European Union: *"Municipal waste consists of waste collected by or on behalf of municipal authorities, or directly by the private sector (business or private non-profit institutions) not on behalf of municipalities"* (Eurostat 2017a).

More important from this thesis' point of view is how is municipal waste defined in the case of the Czech Republic. According to Czech legislation, municipal waste consists of *"all waste generated on the area of the municipality by activities of natural persons and which is listed as municipal waste in the Waste Catalog"* (*Waste Act, §4 (7)*). This includes among others all mixed and separated municipal waste, bulky waste or biodegradable waste (Soukopová 2016).

Separated municipal waste is the municipal waste collected by so-called separated collection. By separated collection, it is then meant *"the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment"* (*DIRECTIVE 2008/98/EC, on waste*). Similarly, by definition in the Waste act, it is *"the collection where the waste stream is separated by type, category and nature of the waste in order to facilitate specific processing"* (*Waste act §4 (1) n)*).

There exists essentially two types of separated collection: *separation of dangerous components* and *separation by usable components*. Separation of dangerous components is such, when we distinguish (and separate) dangerous waste[5] from non-dangerous waste. By separation by usable components is meant the situation when the MW is sorted according to the material which it is composed of (Kuraš and Dirner 2006). In this thesis, we stick to the second definition, and thus under separated waste we understand waste glass, paper and cardboard, plastics and metal.

[4] Types of waste according to Kuraš and Dirner (2005) are: waste from extraction, waste from production, waste from consumption and waste generated by waste treatment.

[5] E.g. paint residues, varnishes, solvents, used mineral oils, medicaments, fluorescent tubes, vacuum tubes, batteries and accumulators, refrigerators.

1.2 MUNICIPAL WASTE MANAGEMENT AND THE ROLE OF WASTE SEPARATION IN THE CZECH REPUBLIC

Municipalities play a very important role in WM. Czech law considers municipalities as producers of municipal waste at their territory. Municipality becomes a waste producer from the moment, when *"the non-entrepreneur natural person deposes the waste in a place designated for that purpose; the municipality will at the same time become the owner of this waste"* (Waste act No. 185/2001 Coll. §4 (1)). As a result, the responsibilities of waste producer associated with municipal waste management lies mostly at municipalities[6].

The very concept of WM itself includes a wide range of activities. In the first place, we of course talk about, *management of already generated waste*[7], namely its utilization and disposal. Furthermore, it includes also the *prevention of waste generation* and the subsequent *care of disposed waste* (*Waste act §4 (1), d)*). WM activities operate in accordance with its two main objectives (Kuraš and Dirner 2006):

- To prevent waste generation or to reduce waste
- To manage already generated waste in such a way, that they can be used as secondary raw materials (in their original or modified form) as much as possible while disturbing the environment as minimal as possible

Apart from the general legal obligations for waste producers, the municipalities have further rights and responsibilities (*Waste act, §17*), to name a few:

- The municipality issues a generally binding municipal decree that defines the system of collecting, transporting, separation, utilizing and removing municipal waste arising in its cadastral territory
- The municipality is obliged to provide places for the disposal of all municipal waste produced in its cadastral territory. The municipality is obliged to provide separate waste collection facilities for municipal waste (at a minimum of hazardous waste, paper, plastics, glass, metals and biodegradable waste)
- Also, other waste producers (i.e. business individuals and legal entities) who produce waste similar to communal waste may take part in the MWM based on written contract.

The general principles of municipal waste management as a whole system (hereinafter referred to as MWM) then include, according to Kuraš and Dirner (2006):

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[6] These responsibilities are specified in more detail in §16 (1) of Waste act. The key responsibilities, important from context of this thesis, are:

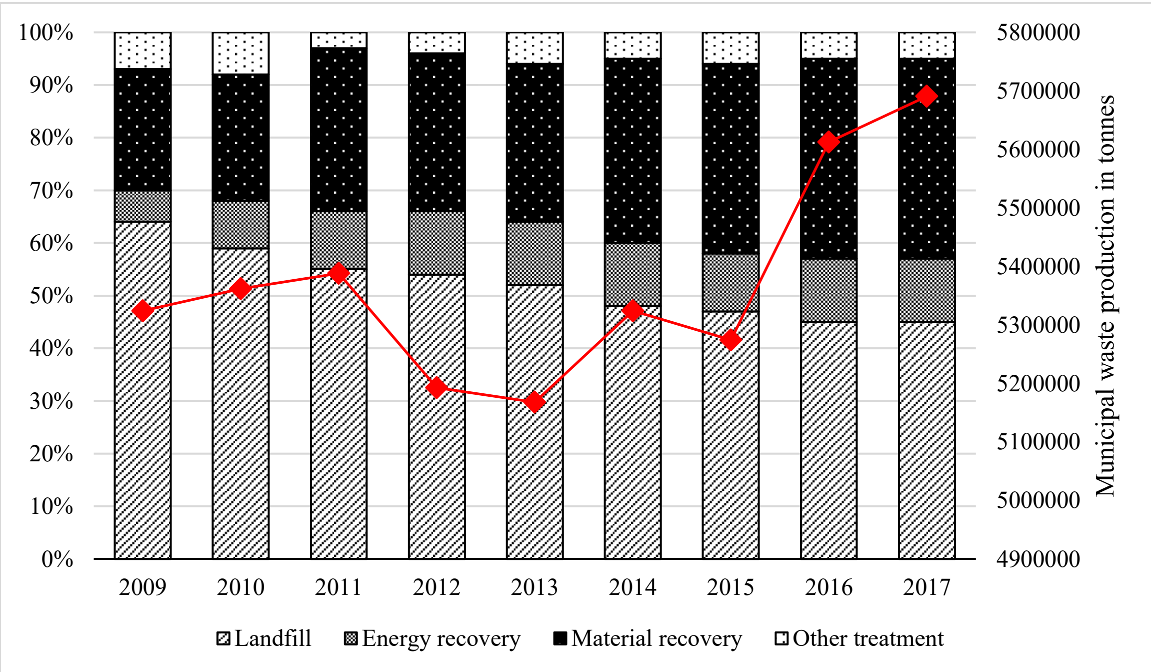
- to *"ensure the priority utilization of waste in accordance with waste hierarchy,*
- to *"collect waste sorted by types and category"* (Waste act No. 185/2001 Coll.)

[7] The English term *waste management* can be translated into the Czech language under 2 different meanings: waste management as whole system (*odpadové hospodářství*) or waste management as management of existing waste (*nakládání s odpady*). Therefore, we try to distinguish between those two by using rather a description of the term.

– waste prevention and prevention of its dangers[8]
– separate collection and utilization of waste components at the source[9]
– separate collection and of usable and hazardous components, their subsequent treatment and processing and separate removal of unusable residues
– rational utilization of residual waste[10]
– landfilling demonstrably unusable residue waste

Even though the landfilling should be used only as last instance method according to the above listed principles, it remains the most prevalent method of treatment of municipal waste in the case of the Czech Republic. This is illustrated in Figure 2.

FIGURE 2
MUNICIPAL WASTE PRODUCTION AND TREATMENT IN THE CZECH REPUBLIC



Source: MoE (2018b), CENIA (2018)

The municipal waste management as a whole system (hereinafter referred to as MWM) consists of a large number of activities and services. Let us mention at least such services that are related to waste separation. It is in the first-place *separate collection of usable components* of municipal waste, then the *operation of civic amenity site*, the *separate collection of hazardous components of municipal waste* and *management of municipal bio-waste*. The first named service is going to be the focus of this thesis, therefore will be described in more detail.

[8] E.g. measures for the production and consumption of packaging and environmentally hazardous products, care of the product throughout its lifecycle

[9] E.g. biodegradable waste (domestic composting, feeding animals, etc.)

[10] E.g. energy recovery of incinerable waste, reusing of building debris, etc.

1.2.1 Methods of separate collection of usable components of municipal waste

The system of collection of separated municipal waste is essentially done in three ways: *collection at civic amenity site*, collection via *collection points* and so-called *curbside collection*. The primary separation of waste according to material is basically done by the citizens that participate in the waste separation: they separate the waste according to waste material and subsequently they either carry their separated waste to the amenity site or collection point and leave it there, or they throw their separated waste into separate waste bins at home.

The civic amenity site offers more types of services and the collection of separated waste is only one of them. Multiple large containers for separated waste are typically available[11] to the users of this service at the fenced area. The staff of the site could also be available to direct users in order to separate the waste correctly. Establishment of civic amenity site is reasonable only for larger areas, optimally for at least 2000 inhabitants (Kuraš and Dirner 2006). The biggest advantage of this system is the high quality of separated waste. It generates, however more disadvantages compare to other systems, e.g. large (driving) distance for the participants, limited opening hours or costly operation and maintenance of the site (Struk 2017a). Nevertheless, we are going to consider this type of waste separation system as supplementary to other two. Hence we will not describe it in any more detail.

The most common collection method in the Czech Republic is currently collection using collection points[12]. In order to collect separated waste, the groups of larger containers are strategically placed on the on the territory of the municipality to make an optimal network of storage containers. These groups that are called collection points include containers for various types of waste material. Containers in the collection points are typically larger with container volume between 500 and 3,500 dm^3. The separated waste from the containers at the collection point is then taken away by collection trucks, each material separately. The advantage of this system is low operating costs; the disadvantage is however low efficiency of such system (Kuraš and Dirner 2006).

The last method, the curbside collection, takes place directly at the house or household level. Every participant has smaller bins or bags (volumes typically between 80 and 360 dm^3) available to separate own waste. These bins or bags are then at given date positioned at the edge of the property to be accessible by collection trucks. This system is the most convenient one for the participants and also the most effective one regarding waste separation. In the same time, it is a more costly method then collection point system (Struk 2017a).

1.2.2 EKO-KOM system

EKO-KOM system is a recycling system for *packaging waste*, which is organized by EKO-KOM company. This system forms an integrated part of WM as it is based on the model practiced all over the EU (Hřebíček et al. 2009). The principal idea is based on the "polluter pays" principle and the "extended producer responsibility" principle, when the main responsibility for packaging waste

[11] This is not the rule, however. The arrangements of civic amenity sites depend on its operator.

[12] Sometimes called also delivery method (Kuraš and Dirner 2006) or drop-off site system (Struk 2017a).

pollution should lie in those who produce it. The goal is co-participation and cooperation with packaging producers and other manufacturers in order to ensure the collection, the take-back and the utilization of the relevant components of municipal waste[13] (MoE 2014).

EKO-KOM is a non-profit organization that acts primarily as a mediator among the various actors on the market and municipalities play a role in the system like one of these actors. Its functions, powers and duties are derived from the law (Waste act No. 185/2001 Coll., stipulates the obligation to take back and use packaging waste). The company primarily levy fees from distributors of packaged goods, provides advice on waste issues. Furthermore, it cooperates with the Ministry of the Environment for which it keeps records of packaging, waste and its use. By its operation, the system also helps to meet environmental policy goals and requirements. It coordinates cooperation between waste processors and recyclers. EKO-KOM is since 2000 the exclusive licensee of *"Green Dot"* in the Czech Republic. Its clients are accordingly entitled[14] to use the internationally recognized symbol Green Dot (EKO-KOM; Hřebíček et al. 2009).

Most importantly from this thesis' point of view, EKO-KOM also cooperates with municipalities. Currently are nearly all municipalities involved in the system as seen in Table 1. This cooperation is based on contract and consists of providing free rental of collecting containers, providing rewards for the collection of sorted waste[15], or mediating educational activities by EKO-KOM. Municipalities, on the other hand, are obliged to record and regularly quarterly report data about their waste separation system.

TABLE 1
INVOLVEMENT OF MUNICIPALITIES IN THE EKO-KOM SYSTEM

	2012	2013	2014	2015	2016
Number of municipalities[16]	6,025	6,057	6,073	6,085	6,114
Population	10,488,753	10,471,722	10,483,885	10,479,423	10,515,124
Share of the population	99 %	99 %	99 %	99 %	99 %
Total utilization of waste	607,005 t	635,892 t	690,047 t	730,662 t	793,658 t

Source: EKO-KOM

1.2.3 Financing of waste-separation system

The municipality has several options on how to finance its waste management system, which also includes a waste sorting system. The law lists the fees of the inhabitants primarily (as actual waste producers) to finance municipal waste management. Resources from these fees should, however, be probably used primarily for financing management of residual waste, as there is literally no other option how to finance it. Waste separation system, on the other hand, provides other opportunities

[13] In practice company raises a lot of money from producers of packaging and use at least part of it for dealing with waste.

[14] subject to conditions

[15] For more detailed description of rewards for municipalities see chapter 1.2.2.

[16] Total number of municipalities in the Czech Republic was 6,251 in 2012, 6253 from 2013 to 2015 and 6,258 from 2016 till today (CZSO 2018; 2017).

for financing. These include income from the packaging company EKO-KOM in the form of contractual rewards, and also income from the sale of sorted secondary materials if relevant. If for any reason, the municipality is not able to financially cover the municipal waste sorting system, it must often bridge this deficit from other municipal revenues, creating thus additional pressure on the budget. It is unfortunately often the case in the Czech Republic, as it is clearly shown in Table 2.

TABLE 2
THE AVERAGE COSTS AND REVENUES OF MUNICIPALITIES FOR SORTED COLLECTION IN 2016 ACCORDING TO EKO-KOM

Municipal size	Costs of separated collection	Income from EKO-KOM	Revenue from the sale of secondary materials	Difference in costs and revenues
(Number of inhabitants)	(CZK per capita)	(CZK per capita)	(CZK per capita)	(CZK per capita)
Up to 500	195.2	142.8	32.8	19.6
501 – 1,000	168.7	135.1	24.0	9.6
1,001 – 4,000	155.4	111.7	22.7	21.0
4,001 – 10,000	153.0	110.9	18.1	24.0
10,001 – 20,000	139.7	108.1	21.2	10.4
20,001 – 50,000	142.3	105.7	26.3	10.3
50,001 – 100,000	129.3	99.3	25.6	4.4
100,000 - 1 mil.	143.1	105.6	22.1	15.4
over 1 mil.	266.7	101.8	9.9	155.0

Source: Arnika 2017

Charges from residents

According to the Waste Act 185/2001 Coll. the municipality has, in particular, the opportunity to charge for the waste management services it provides to its residents. By these services are meant gathering, collection, transportation, sorting, use and disposal of municipal waste. These payments can be made in one of the following three forms: on the basis of a contract, in the form of a municipal waste charge set by a binding decree, or in the form of a local fee under the Local Fees Act. The specific differences between these charges are described in Table 3 below. These payments, as defined by the law, should be used to cover all services related to the management of municipal waste, including the waste sorting system. However, their amount is often tied in some way to the collection of *mixed* municipal waste, whether it is a payment based on the number of containers, the volume of waste, the frequency of shipment or other.

TABLE 3:
OVERVIEW OF FEES FOR RESIDENTS RELATED TO WASTE MANAGEMENT IN THE CZECH REPUBLIC

	Fee for the accumulation, collection, transport, separation, recovery and disposal of municipal waste from natural persons on the basis of an agreement	**Fee for municipal waste**	**Local fee for operation of a system of accumulation, collection, shipment, separation, recovery and disposal of municipal waste**
Legislation	Waste act, §17	Waste act, §17a	Local fees act, §10b, c
Form	Written contract	Generally binding decree	Generally binding decree
Payer	Natural persons/ Individuals	Every natural person who generates municipal waste (the taxpayer is the owner of the realty where municipal waste is generated)	A natural person with a permanent residence in the municipality or a natural person who owns a building designed or used for individual recreation
Recipient of the revenue	Municipality		
Use of the revenue	Operation of gathering, collection, transport, separation, utilization and disposal of municipal waste		
Fee amount	The amount of the fee explicitly specified in the contract depends on the agreement of the parties (often derived from the waste volume and the frequency of collection)	The maximum amount of the fee is set according to the estimated eligible costs for the MWM system. It reflects the number and location of containers intended for the disposal of waste belonging to individual properties, or according to a number of users of dwellings.	CZK 250 per person per year + the amount determined according to the actual costs for collecting and disposing of mixed municipal waste in the previous year, up to CZK 750 per person per year (costs per person are set in the decree)

Source: Adapted from CENIA

Approximately three-quarters of municipalities in the Czech Republic are collecting fees in the form of the local fee (on the basis of Local fees Act). The fee for municipal waste (on the basis of Waste Act, §17a), which allows for motivation payments[17], is used less frequently, by only about one-fifth of municipalities[18] (Vrbová 2016).

At this point, it is important to note once again, that MWM is chronically long-term deficient in the Czech Republic. Charges from inhabitants cover only about 54 % of all costs of MWM[19], adding other sources of revenue (see next chapters), municipalities must still finance on average the

[17] For example payments according to container volume, number of containers, collection frequency, etc.

[18] These were typically smaller municipalities with number of inhabitants less than 4000. For bigger municipalities is collecting such fee too arduous administratively.

[19] The cause can differ from political to legal reasons (there can be fee ceiling implemented, etc.)

remaining 31 % of costs per person from own resources (Balner, Vrbová 2017). Since costs of management of separated waste make just fraction of costs (on average 18,5 % in 2016) of overall MWM, we assume income from fees to be used to finance other costs of MSW[20] than costs of the waste separation system. Hence this source of financing plays only the marginal to none role in our analysis.

Contractual rewards from EKO-KOM company

Another possible income of municipalities is the contractual reward of municipalities from EKO-KOM company (EKO-KOM 2018c). When joining the EKO-KOM system under the *Contract on the Recycle and Utilization of Waste from Packaging*, the municipality is entitled to a fee for securing the take-back and subsequent recovery of packaging waste.

The amount of the reward is calculated on the basis of the amount of sorted waste. The fee consists of several components: reward for securing the take-back points, the reward for the operation of the take-back points, remuneration for ensuring the recovery of packaging waste and remuneration for ensuring the energy recovery of packaging waste. Some of these components may also be increased by the bonus component provided the conditions specified in the contract are met.

The total amount of the fee reflects the success of the system in the municipality and is often used as an indicator of the efficiency of the system. The fee is not primarily to cover all costs, but rather serves as a contribution by which municipalities can reduce the total cost of operating a municipal waste sorting system. Even so it, in fact, covers perceptible part of municipal costs of the waste separation system, as illustrated in Table 2. The reward is also purpose-bound[21] by the contract, a municipality can only use it for the purpose of management of waste, which contains packaging waste – typically separated waste (EKO-KOM 2018c).

Income from the sale of sorted secondary materials

Another possible additional source of income are revenues from the sale of sorted waste as secondary materials. Even though in some recycling system this kind of income is the main source of financing and effectiveness (Lavee 2007), in the Czech Republic, however, not all municipalities report this income. For example, the research of EKO-KOM company suggests, that only about 27 % of municipalities in the Czech Republic do generate this income (Balner and Vrbová 2017).

On average in the Czech Republic makes income from the sale of sorted materials only about 2.82 % of income for overall MWM. If we include only income directly tied to waste separation (i.e. income from EKO-KOM, revenue from the sale of secondary materials and payment of collective redemption systems for electrical and electronic equipment[22]), the share then makes 13.58 %

[20] In case other services, such as collection of MMW, income from inhabitants is the only resource.

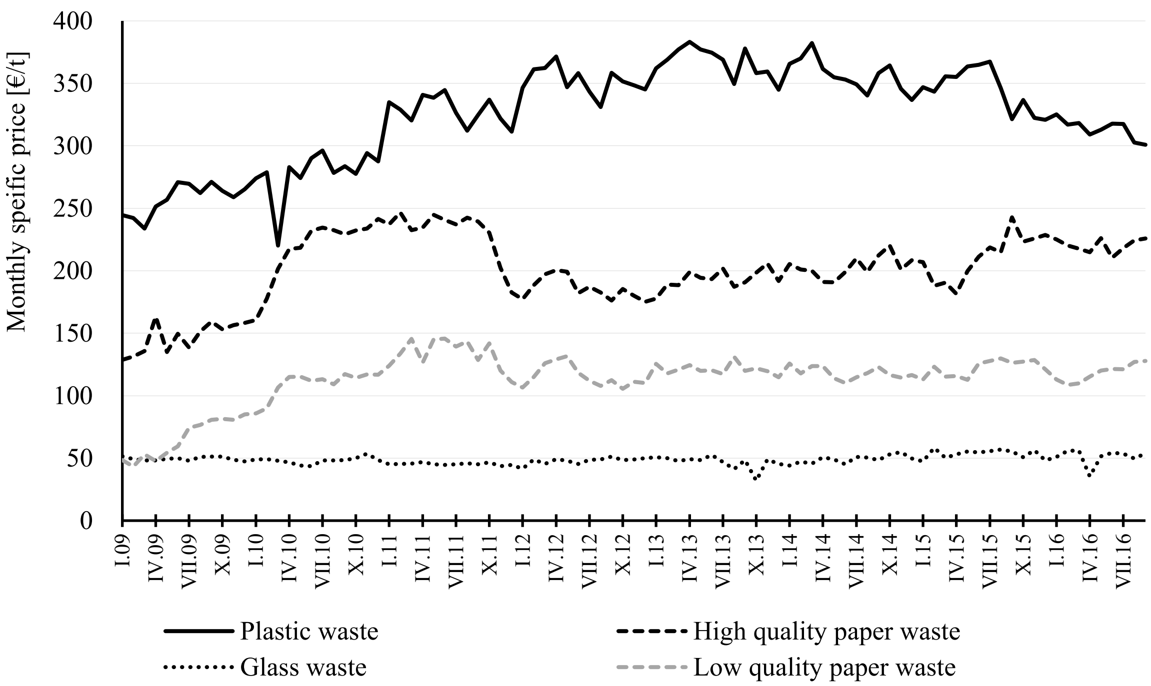
[21] In particular bound to the expenditures on the municipal waste collection system and waste separation, to the system for the utilization of municipal waste containing packaging waste, to education and information programs for the citizens of the municipality (primarily about waste separation and recovery of packaging waste and to advisory, consultancy and design activities regarding waste collection and utilization.

[22] The payment of collective redemption systems for electrical and electronic equipment makes only marginal portion of municipalities' income hence its description is not expanded any further.

(Balner and Vrbová 2017), the main source of income for waste separation systems remains the contractual reward from EKO-KOM.

The biggest problem with income from the sale of separated waste is that its height highly depends on the price of secondary materials. The market for secondary materials is relatively unstable, as the demand depends on a number of external factors (*Jak se recykluje plast* 2018). It depends in the first place on the price of substitutes, i.e. raw materials[23]. Price of secondary materials further depends on international trade with waste. The big factor makes political decisions that often influence international trade of waste. For example, European countries recently faced a sudden drop in demand for plastic waste, as a result of China's government decision to limit imports of plastic waste (e.g. EKO-KOM 2017; Dohnal 2018). Such interventions not only increase the costs of sorting systems for municipalities but also negatively affect people's motivation for sorting, which is an important aspect of the system’s operation. Fluctuations in prices at European market for separated waste are illustrated in Figure 3.

FIGURE 3
DEVELOPMENT OF PRICE INDICATORS FOR SORTED SECONDARY MATERIALS IN EU-28



Source: Eurostat (2017b)

[23] For example, price of separated plastic materials is influenced by fluctuation of oil price as strategic resource.

1.2.4 Municipal expenditures for waste separation

The largest fraction of waste management expenditure in municipalities in the Czech Republic is spent on mixed municipal waste. Expenditure on separated collection is ranked second. Nevertheless it still makes only a relatively small fraction of total costs (see Table 4).

The data about the composition of the expenditure for the municipal waste separation is somehow difficult to follow. Soukopová (2016) discusses in detail individual data sources for the municipal waste management expenditure analysis in the case of the Czech Republic. There are three institutions that track MWM expenditure: the Czech Statistical Office (CZSO), Ministry of Finance of the Czech Republic (MoF) and authorized packaging company EKO-KOM. Unfortunately, none of those publishes specific composition of expenditure regarding waste separation, but rather the aggregate results[24].

TABLE 4
SELECTED COSTS IN 2016 (IN CZK / INHABITANT / YEAR)

Municipal size [number of inhabitants]	**Mixed municipal waste**	**Separated collection**	**Civic amenity site**	**Bulky waste**	**Trash cans**	**Hazardous waste**	**In total**
Up to 500	524.2	195.2	72.1	65.0	17.4	32.9	916.4
501 – 1,000	507.6	168.7	83.1	60.1	16.1	27.4	858.0
1,001 – 4,000	483.9	155.4	124.2	70.0	23.2	19.5	854.1
4,001 – 10,000	480.3	153.0	117.4	75.4	45.4	17.3	884.4
10,001 – 20,000	500.0	139.7	141.4	71.5	55.9	14.3	969.7
20,001 – 50,000	502.4	142.3	94.2	75.7	53.4	16.2	940.5
50,001 – 100,000	503.5	129.3	111.7	77.8	47.4	16.8	898.7
100,001 – 1 mil.	549.5	143.1	98.6	82.4	28.0	6.1	791.8
Over 1 mil.	675.5	266.7	52.8	11.3		4.4	994.4
Czech Republic Total	524.7	166.1	102.4	63.3	42.0	16.1	900.0

Source: EKO-KOM (Balner and Vrbová 2017)

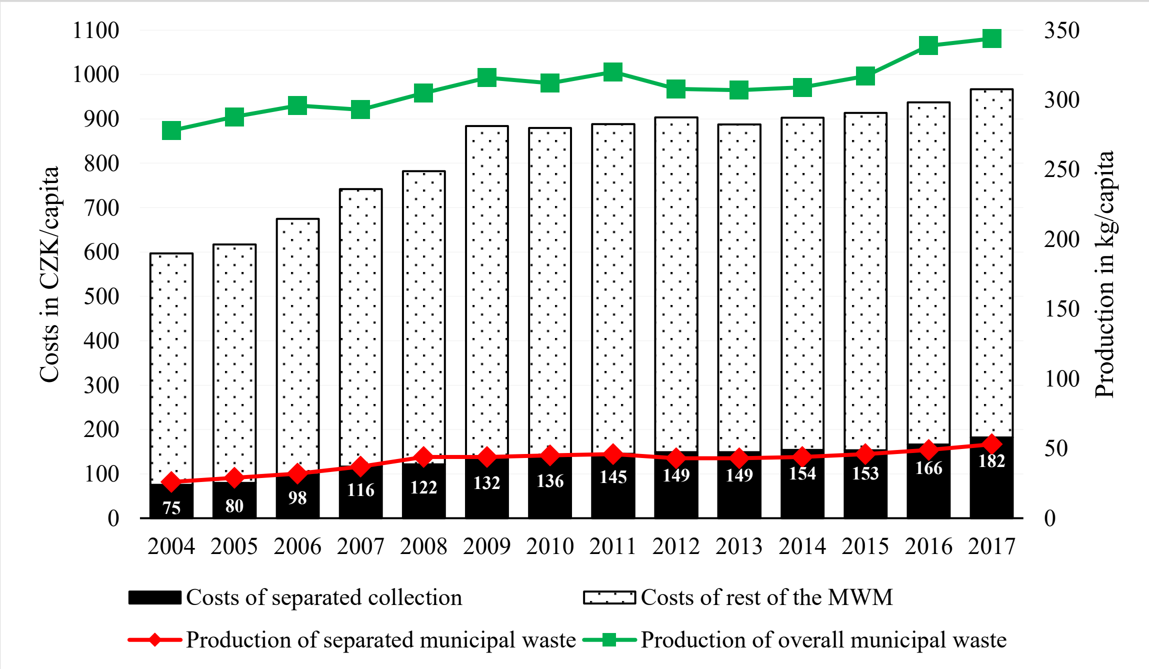
We assume that the composition of municipal expenditures for municipal waste separation will be similar to the composition of expenditure for overall MWM (adapted from Soukopová (2016)):

- Collecting and transporting of separated municipal waste
- Use and disposal of separated municipal waste
- Waste prevention
- Monitoring of separated municipal waste managing
- Other separated municipal waste treatment

[24] This is also the reason, why the primary data regarding waste separation will be collected for the purposes of the thesis.

In regard of costs of municipal waste separation, we can observe the steadily increasing trend, as in the case of total costs of MWM (see Figure 4). This trend is, however, in part also influenced by increasing trend in the municipal waste production.

FIGURE 4
COSTS AND PRODUCTION OF MWM IN MUNICIPALITIES IN THE CZECH REPUBLIC



Source: EKO-KOM (Balner and Vrbová 2017; Balner and Urban 2018), CZSO (2018b)

1.3 MOTIVATION SYSTEMS FOR WASTE SEPARATION

The waste separation systems are typically built on the voluntary participation of citizens. It is citizens who primarily produce and separate the waste and the effectiveness and success of the waste separation systems depend heavily on their behavior. The knowledge of the importance of citizens participation plays a major role in the establishment and settings of the municipal waste separation systems (Folz 1995).

The key role in the citizens' participation in waste separation services is then the motivation. In principle, there are two kinds of factors that can motivate people to sort their waste: *extrinsic* and *intrinsic*. Intrinsic motivation represents the internal satisfaction of an individual from some activity. Extrinsic incentives, on the other hand, are provided from the outside (typically by public authorities) with the aim to achieve a certain type of behavior (De Young 1986).

1.3.1 Intristic motivation

In the context of this thesis, waste separation can provide utility to the separator in the form of satisfaction, i.e. feeling good about themselves. De Young (1986) argues, that intrinsic motivation can be drawn from multiple relative independent sources in the case of participation in recycling schemes:

- *"frugality (e.g. satisfaction from finding ways to avoid waste, repairing things rather than discarding, saving items for potential future use)*
- *self-sufficiency (e.g. finding new ways to become self-sufficient, rediscovering ways people used to do things)*
- *participation (e.g. a chance to do things that make a difference, participation in activities involving the community, participation in bringing sense/order to world)*
- *luxuries (e.g. being a citizen of the richest country, having luxuries of civilized society)"*

Other authors (e.g. Vining et al. 1992; Abbott et al. 2013; Gould et al. 2016) make the case that *altruism*, including impure altruism in the form of so-called warm-glow, and the *environmental concern* are important drivers of recycling behavior of individuals or households.

Authorities, i.e. municipalities in our case, have only limited options on how to influence the intrinsic motivation. It can only educate citizens about environmental impacts, eventually, about some advantages of waste separation compare to other waste treatments.

1.3.2 Extrinsic motivation

Extrinsic motivation is such, that depends on some external factors called incentives. This kind of motivation is widespread in the case of public sector, in practice, it turns out that best results are achieved through motivation based on economic incentives. It is very easy to influence inhabitants' behavior by adopting some incentive. Such incentive can, of course, take a number of forms too, in this thesis, they are divided into two groups: *monetary* and *non-monetary* incentives.

Monetary incentives use some sort of rewards that encourage desirable behavior, while non-monetary incentives are oriented towards social influence and convenience of participation in the recycling schemes.

Monetary incentives for waste separation

In the case of municipal waste separation, two types of monetary incentives can be used, according to De Young (1986): municipality can offer to buy out the separated waste from the citizens or to offer some kind of monetary rewards or discounts in the case that citizens engage in the municipal waste separation.

The first option does require no other explanation in our estimation. Therefore, we look closely only in the latter case. We consider the separated waste collection systems as being part of monetary incentives because they can be a source of either rewards or discounts, both in monetary terms. For example, in the case of the Czech Republic, the disposal of the separated waste is free of charge[25].

The risk of using monetary incentives is their undermining effect on other sources of motivation, especially on intrinsic motivation. This problem was observed by many authors (e.g. Deci 1971; McCarty and Shrum 1994; Bowles 2008). The empirical evidence laid by Meneses and Palacio (2006) support this proposition. Abbott et al. (2013) even argue, that crowding out if intrinsic motivation by the monetary incentives becomes permanent. Which means that once the monetary incentives are implemented, the general motivation to participate in the waste separation without it decreases rapidly. The use of non-monetary incentives is therefore advised.

Non-monetary incentives for waste separation

Non-monetary incentives then target other factors of motivation than monetary interest. Among the factors most cited in the literature belongs especially personal *convenience* and the *social influence*.

In the domain of personal convenience, the municipalities should focus on the suitable infrastructure (Gould et al. 2016), especially then on the distance, the participants have to travel in order to dispose of separated waste (Struk 2017a) and the time that participant needs to spend on it (Jamelske and Kipperberg 2006).

The social factor, i.e. the general perception of municipal waste separation in the society, can be targeted for example by the information incentives (Kirakozian 2016), such as can be information campaigns about why to separate, what to separate, where to separate, etc. The knowledge gaps can be a very significant barrier to the success of the waste separation system in the municipalities (McDonald and Ball 1998).

1.3.3 Incentives in the case of the Czech Republic

What possibilities municipalities in the Czech Republic have, regarding the economic motivation of waste separation, then? Although the residents' payments for the waste separating system are united with other municipal waste management services, its factual linking to mixed waste containers causes the sorting of waste to be perceived by the inhabitants as free of charge (Havel 2017). Municipalities are trying to motivate residents to sort waste by trying to provide them with the most convenient sorting system.

Depending on what kind of charge the municipality chooses, we can distinguish between two types of economic-motivational tools in the Czech Republic[26] (Havel 2017): incentive payments based on a payment derived from mixed waste production and incentive discounts for per capita payment.

As already mentioned, the first set of tools is derived from the production of mixed waste. The municipalities can choose to apply some monetary incentives based on that. The whole principle of the economic motivation of the population in the Czech Republic is then as follows: if people sort

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[25] Even though the problematics payments is slightly more complicated, see chapter 1.2.3.

[26] Note, that this motivation serves not only for waste separation, but also for reducing the total volume of waste.

waste, the volume of their mixed waste will be reduced, and they will pay less as a result. There are several types of motivation payments currently used in the Czech Republic, where residents' or households' payments depend on how much waste they produce:

- payments based on the weight of mixed municipal waste (so-called PAYT systems, i.e. "pay as you throw"[27])
- payments based on the frequency of the collection of the mixed municipal waste by the collection truck
- payment for each mixed waste removal
- payment for waste according to the volume of the mixed waste container

Incentive discounts on a per capita payment may take several forms too, such as discounts derived from the aggregate amount of sorted waste, ISNO (Integrated Waste Management System) or a discount derived from the volume of the mixed waste container.

As shown by Šauer et al. (2008) or Struk (2017b), motivation payments systems show the best efficiency in reducing the volume of mixed municipal waste. However, they can only be used by municipalities that have a waste-related payment system in place. Such systems are mainly used by smaller municipalities with a predominance of family houses (Vrbová 2016, p. 115). It is due to the logistic difficulty of collecting charges where a large number of entities use common containers to collect mixed municipal waste, as is the case for apartment buildings or housing estates in larger cities. Most of the municipalities are hesitant to implement motivation payments due to fear of high costs. This premises turned out, however, to be unproven by Slavík and Pavel (2013) in the Czech Republic case.

One of the most important factors for the success of waste separation systems is undoubtedly well-available collection network. Availability of collection is best represented by the distance to it. This fact is well-illustrated that collection based on curbside is much more successful than drop-off collection (Struk 2017a). Experience form the Czech Republic suggests, that for 5 % population to separate waste there is the average distance at least 400 m to nearest collection point needed and for 65 % population, it is average 150 m to on average (EKO-KOM 2018a). Every municipality is legally obliged to determine location, where inhabitants can put their (separated) waste. It depends on each municipality, which density and consequently average distance to collecting points they choose (EnviWeb 2010). Collection network in case of Czech Republic is, according to EKO-KOM, in very good shape. In 2016 there was the average distance to nearest collection point 96 m (Grolmus 2017).

With the way the municipal waste charges are set in the Czech Republic, i.e. the inhabitants pay only once for all types of waste management services, the other types of the motivation of the population to sort waste is very intricate. Unlike in the Scandinavian countries or in Germany, which use the back-up systems to a large extent[28], we have a limited possibility of economic motivation of the population here. The sorting system in the Czech Republic is mainly based on volunteerism,

[27] For description of this method see Bilitewski (2008)

[28] In the Czech Republic, the only back-up system is used for some of glass bottles. This system, however, operates outside of MWM hence is not considered in this thesis.

so personal motives and educational activity plays a major role here[29] (Havel 2017; Slavík et al. 2018). For this reason, we assume that the personal motives of the population play a key for the success of municipal waste sorting systems role in the Czech Republic.

The task of the municipalities in this respect is primarily to inform households about the opportunities offered by waste management, such as the collection of mixed waste, ways of sorting waste, handling bulky and hazardous waste, etc. In this way, municipality officials should motivate residents to behave in a manner consistent with the desired waste management hierarchy.

The biggest influence factors to the willingness of the citizens to participate in the municipal waste separation are according to Šauer (2004):

- awareness about how to separate the waste properly (can be influenced by the provision of relevant information by the municipalities)
- household storage of separated waste
- presence and availability of containers for separated waste in the municipality
- the practicality of containers use
- subjective assessment of conditions for the waste separation in the municipality
- subjective evaluation of Czech legislation in relation to the promotion of household waste separation and securing of secondary raw materials for industry

[29] Even though as Slavík et al. (2017) point out further, influence of educational activities has probably reached its potential in the Czech Republic as participation rate grows very slowly or even does not grow any more lately.

2 EVALUATION OF WASTE SEPARATION SYSTEMS

In order to decide, whether a specific waste management system worth to implement or sustain, we need to be able to evaluate systems' performance somehow. Evaluation of performance in public sector is however somewhat more complicated than in private sector: public organizations (such as municipalities) typically do not generate profit (or at least it should not be their main goal). In the private sector, we can then simply judge organizations' performance by the profit expressed in money terms. We do not have this simple option in the public sector, because the primary aim of the public organization is typically to provide some sort of public service. Public service's value is not solely focused on money[30], but rather on public satisfaction[31].

At this point, we would like to discuss the nature of MWM briefly. One would imply, from what has been said about the case of MWM in the Czech Republic in this thesis, that MWM falls under the concept of public good resp. public service. However, it is not entirely the case. It is namely important to distinguish between *public goods/services* and *publicly provided goods/services*, as Malý (1998) emphasizes. Definition of public good according to economic literature requires the fulfillment of two features: the consumption of such good must be non-rival and non-excludable. As we can read from Table 5, MWM would fall rather under private good category. For example, a waste separation system allows exclusion when waste bins are placed in the fenced area and only some citizens are allowed access. In the situation, when separation containers are quickly overfilled, we then talk about rival consumption. It is due to the difference in the quality of the service: only those who come first consume the best quality (e.g. clean surroundings of collection point), for those who come after overfilling of containers the quality of consumption is decreasing.

TABLE 5
CLASSIFICATION OF TYPES OF GOODS BY CONSUMPTION ATTRIBUTES

Consumption	Exclusion	
	Feasible	*Not feasible*
Rival	(pure) private goods	club goods
Nonrival	common-pool goods	(pure) public goods

Source: Musgrave and Musgrave (1984), adapted from Malý (1998)

The fact that MWM in the Czech Republic is in reality publicly provided service with the monopoly of the municipality as a provider has serious implications to the evaluation of the efficiency of waste separation systems. In the case of public good, a state intervention may reduce or even eliminate market failure thereby achieving a higher level of resource allocation efficiency. On the contrary when states intervene in the provision of private good loss of efficiency usually takes place as a consequence of redistribution effect (Malý 1998).

[30] In the sense of gaining huge amount of profit. The use of public money should always be efficient without unnecessary waste of money.

[31] At reasonable costs, naturally.

That being said, this is not the place to judge legitimacy (or whether it is good thing or not) of the governing authorities deciding what goods or services they provide publicly. We take it rather as a fact: MWM is in the case of the Czech Republic publicly provided good, and as such, it is part of the public sector. Hence, we approach the evaluation of municipal waste separation systems from public sector perspective and subsequently use techniques intended for evaluation of public sector. The primary goal of waste separation system as we see it in the case of the Czech Republic is definitely not to earn any profit (see the chronical lossability of it in the Czech Republic). The objective of MWM is then to satisfy inhabitants demand for the most effective and environmental waste removal as possible[32].

In the same time, we will be deliberately trying to avoid the use of term public service for a description of the waste separation system, but we will be using alternative terms *public sector service* or *environmental service*[33] in this context instead.

2.1 ECONOMIC EVALUATION IN THE PUBLIC SECTOR

One of the ways how to evaluate the performance of the public organization, public project or a certain way of providing public sector service is to evaluate it using so-called 3E model (Soukopová 2016). Decision-making, especially at municipal level, should adhere to the three following principles and target on meeting criterions associated with them: *economy, efficiency* and *effectiveness*. In addition to these three, some authors add fourth principle to extend the model to 4E concerning how the public sector should function, i.e. *equity* (e.g. Johnsen 2005, Oulasvirta 2017).

The principle of *economy* requires producing public sector services at minimum cost, i.e. spending as little resources as possible in order to provide intended service in required quality (Soukopová et al. 2011). When the resources (financial, human or material) are used at the right time, in sufficient quantity, at the appropriate quality and at the most advantageous price, the criterion for the principle of economy is accomplished (Pavel 2008). Economy, in a nutshell, means to minimize costs per unit, the general criterion of economy can be then calculated as follows:

$$Economy \approx \frac{costs}{output\ unit} \tag{1}$$

Another principle, the principle of *efficiency*, requires optimal use of resources which allows as highest scale and best quality of services resulting in most benefit as possible. This principle can be achieved in two ways: either by the effort to achieve the maximum level of goods or services at given resources, so-called augmenting aspect, or by the effort to achieve required output with same quality while minimizing resources, so-called saving aspect (Pavel 2008). Overall efficiency

[32] Compare to concrete objectives of MWM in chapter 1.2.

[33] Under the term of *environmental good* according to definition by Dvořák et al. (2007) fall *"all aspects of the environment for which people express their preferences"*. This definition includes broad variety of goods and services that are closely tied with environment (e.g. air quality, amenities of environment, species variety etc.). Environmental services in this context are then such that preserve consumption of environmental goods for the future (e.g. environment protection, including waste recycling systems). The important inherent feature of the environmental goods/services is non-existence of competitive market for them.

express relationship between inputs and outputs. Again, the general equation of criterion of efficiency can be written in the following form:

$$Efficiency \approx \frac{output}{input} \tag{2}$$

The principle of *effectiveness* then expresses *"the ability to produce the intended, desired or expected effects ev. results"* (Soukopová et al. 2011). Public resources should be used in such manner, that optimum level of objectives is achieved while considering all intended, unintended and external effects of public policy/program. Effective activity should not simultaneously produce other activities or undesirable unintended consequences (Pavel 2008). The equation shows the relationship between resources (i.e. inputs) and all actual effects (i.e. outcomes):

$$Effectiveness \approx \frac{inputs}{outcomes} \rightarrow vs.goals \tag{3}$$

Last, but not least, the principle of *equity* reflects fairness and justice in all aspects of evaluated public program. There must not be present any discrimination of any kind. Especially important is then equity in case of resulting outcome[34]. Equity is *"the distribution of outcomes across different individuals and groups in relation to inputs over all services"* (Johnsen 2005).

2.2 METHODS OF ECONOMIC ANALYSIS OF MWM

A number of analysis methods have been invented that aim to measure above mentioned principles in the public sector. These methods are also divided into a various number of groups and subgroups according to their features. It is not our place to describe all methods in this thesis so that they will be presented only as a brief overview, based on Soukopová et al. (2011)[35].

Methods of economic analysis can are divided between *qualitative* and *quantitative* approaches. Under the first category fall for example methods as Benchmarking, Brainstorming, SWOT analysis, Delphi method, Comparison of scenarios, etc. Quantitate methods are further divided into groups of *mono-criterion* and *multi-criteria* methods.

Single-criterion methods use as for evaluation of public good or service provision only one criterion (usually some ratio), that is either compared to a benchmark value or between values of criteria among a number of evaluated alternatives. Among single-criterion methods we include, for example:

[34] As equality in volume and quality of provided public good or service. Complete equality of outcome is generally nearly impossible to achieve, sometimes even not desirable. Perhaps better designation would be in this case equality of income from the perspective of an individual (i.e. user of good /service).

[35] For detailed description of methods see for example Soukopová et al. (2011, pp. 103–136)

A) *Financial methods*:

- *Static methods* – that do not take the aspect of time into consideration
    - Average Annual Return,
    - Profitability method,
    - Average Percentage Return,
    - Pay Back period
- *Dynamic methods* – that do take the aspect of time into consideration
    - Net Present Value (NPV)
    - Internal Return Rate (IRR)
    - Rentability Index

B) Cost-output methods:

- Total Cost Assessment (TCA)
- Cost-minimization Analysis (CMA),
- Cost-utility Analysis (CUA),
- Cost-effectiveness Analysis (CEA)
- Cost-benefit Analysis (CBA).

Single-criterion methods, however, often cannot properly reflect the complexity of evaluated good or service. For that reason, there is another eventuality in multi-criteria methods. The real decision, in reality, is often very complex with multiple angles and perspectives. Hence it must be made based on multiple criteria (often even contradicting each other). Similarly, as in the case of mono-criterial methods, also multi-criteria methods can be divided into subgroups. We can distinguish between methods *based on scale and range*, *based on a partial evaluation of variants* or *based on pair-comparisons,* etc. The list of multi-criteria methods includes for example:

- Weighted scoring method
- Partial utility functions method
- Data envelopment analysis (DEA)
- Environmental impact assessment (EIA)

The methods currently most commonly used directly for evaluation of WM are, according to Morrissey and Browne (2004), above all models based on cost-benefit analysis (hereinafter CBA; e.g. Damigos et al 2016; Weng and Fujiwara 2011; Chifari et al. 2017), models based on life cycle analysis (hereinafter LCA; Beigla and Salhofer 2004) and models based on multi-criteria decision analysis (hereinafter MCDA; e.g. Soltani et al. 2015). Soukopová (2016) then considers best methods to evaluate efficiency of MWM being a regression analysis (i.e. parametric approach), DEA, Multi-criteria weighted evaluation, CEA or Minimal value method[36]. Every one of the mentioned methods has its own advantages and challenges naturally. CBA presents clear results easy for decision-makers to understand, on the other hand, it faces some methodological difficulties regarding the evaluation of non-monetary factors. LCA can assess the overall impact on the environment, but it should not be used as the sole base for decision-making. MCDA represents a

[36] This method was created especially for purpose of evaluation of efficiency of municipal expenditure in regard of MWM and was later adopted by Czech Ministry of Environment (MoE) as official method of evaluation. For description and explanation of this method see Struk and Soukopová (2012)

systematic approach to the problem and allows both quantitative and qualitative information to be incorporated. On the other hand, this method can be complicated, and it requires experience in order to make proper decisions (Morrissey and Browne 2004).

Now we face the decision of our own which one of the mentioned methods to use in this thesis. Especially important is to specify the goals of the analysis and subsequently according to our goal choose proper method.

In this thesis, the focus is on municipalities. We do not pursue evaluation of waste separation as a whole concept[37] neither evaluation of the whole system of MWM. We would rather concentrate our attention just on the waste separation in the context of the municipality and its citizens. For that reason, we consider for instance use of LCA as inappropriate in our case. Next, both LCA and MCDA methods are perhaps too complex for our aim, namely to examine effectiveness across various municipalities separately for each one of them. Moreover, such analysis would be probably also too complex to be successfully performed in the scope of a diploma thesis. And finally, the very important partial goal of this thesis is to recognize possible benefits for municipalities from waste separation[38]. Therefore, it was determined that the method of analysis in this thesis would be CBA.

2.2.1 Cost-Benefit Analysis

Because the CBA will be used for evaluation of municipal waste separation programs in this thesis we would like to describe it in more detail. The logic behind CBA is very simple and straightforward: just like in case of any decision of individuals we compare benefits with costs resulting from a particular option. Theoretical basics of CBA are built on *utilitarism* (Seják 1999): we can compute the outcome of the project by adding public costs and benefits into their sum.

CBA evaluates the *effectiveness* of program or policy. It compares the *monetary value* of costs with the monetary value of benefits. One of the advantages of CBA is that it incorporates not only primarily monetary items, but also evaluates non- monetary factors. By comparison of overall costs and benefits, we get *net value* (positive or negative) of the program (Boardman et al. 2006):

$$Net\ Value\ =\ Total\ Benefits - Total\ Costs \tag{4}$$

An alternative to the net value could also be an expression in the relative form, when instead of value differential it is the ratio of total benefits and total costs, so-called Benefit-Cost Ratio, as a criterion of evaluation (Hanley and Barbier 2009):

$$\frac{B}{C} = \frac{Total\ Benefits}{Total\ Costs} \tag{5}$$

---

[37] I.e. as one of the fazes of the recycling process

[38] In order to explore the frequent perception that there is no benefit from it at all.

CBA consists of major ten steps, according to Riegg Cellini and Kee (2015, p. 495):

1. Setting the framework for the analysis
2. Deciding whose costs and benefits should be recognized
3. Identifying and categorizing costs and benefits
4. Projecting costs and benefits over the life of the program, if applicable
5. Monetizing costs
6. Monetizing benefits
7. Discounting costs and benefits to obtain present values
8. Computing a net present value
9. Performing sensitivity analysis
10. Making a recommendation where appropriate

European union's guideline suggests dividing analysis into two parts: a *financial* and *economic analysis*. The financial analysis covers only financial aspects of the project, while economic analysis adds projects' externalities, such as social or environmental aspects. However, procedure remains the same for both (EC 2014).

We can describe the individual steps of CBA as follows, based on Boardman et al. (2006):

Setting the framework for the analysis

This is an introductory part of the analysis, and it is necessary to specify aims of the evaluated project or policy correctly. Sometimes it is also useful to recognize, describe and consider other alternatives of the evaluated project, especially when CBA is a basis for future decision making. There can be either generally defined aims or specified quantitative goals, depending on the character and focus of the analysis.

Deciding whose costs and benefits should be recognized

Next, it must be specified what (or who) is a subject of the analysis, i.e. whose costs and benefits will be considered. It must be decided on how big area will be in the focus of this thesis, from local levels to Worldwide level. The relevant group of stakeholders must also be identified in this step and their relations to the project in focus, most importantly, whether the projects generate any costs or benefits to them.

Identifying and categorizing costs and benefits

In this step, all impacts (i.e. inputs and outputs) of the project must be recognized, and it must be determined, whether they fall into the category of costs or benefits. At the same time, the measurement methods of the impacts must be determined.

Projecting costs and benefits over the life of the program, if applicable

In the evaluation process, the life-span of the project must be considered. Subsequently, all previously defined costs and benefits must be addressed in the time perspective, from both the scheduling and the duration viewpoint.

Monetizing relevant costs and benefits

From the nature of CBA, the monetary value must be assigned to all assumed costs and benefits. Note that there can be two types of costs / benefits, i.e. market and non-market ones. In the case of marketed impacts, the monetary value is directly its market price, but in the case of impacts that do not have a price, the alternative techniques must be used[39]. The monetary value can be then determined either in real or nominal terms.

Discounting costs and benefits to obtain present values

The discounting of values of costs and benefits according to corresponding interest rate is performed, if the project /policy is spread over several periods of time, in order to obtain the present value of them. It is recommended to use two separate rates for calculating financial and economic analysis (EC 2014). The financial analysis examines financial cash flow, so it is appropriate to use a discount rate that reflects the opportunity cost of capital.

The so-called *social discount rate* was created for the purposes of economic analysis in CBA. It should reflect *"society's impatience or preference for consumption"* according to Riegg Cellini and Kee (2015, p. 519). The use of the social discount rate and the discounting in general is one of the main subjects of the critique of CBA (Hwang 2016).

Computing a net present value

Subsequently, the net present value (hereinafter NPV) is calculated from the present values of costs and benefits. The equation takes the following form (Seják 1999, p. 31):

$$NPV = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} \tag{6}$$

where:

T stands for the final time horizon when the project completes its economic life

t stands for a given time period

r stands for the discount rate

B_t stands for the benefit in the period t

C_t stands for the cost in the period t

Alternatively, the ratio of costs and benefits can be calculated in order to obtain the efficiency criterion (Hanley and Barbier 2009)

$$\frac{B}{C} = \frac{\sum_{t=0}^{T} B_t / (1+r)^t}{\sum_{t=0}^{T} C_t / (1+r)^t} \tag{7}$$

The resulting value of NPV is then criterion of efficiency, and it is either compared across the alternatives or to the benchmarking value. The benchmarking value is in the case of NPV calculated from differential B-C equal 0, i.e. values in the interval $(0; \infty)$ are considered efficient, values in the interval $(-\infty; 0)$ are considered inefficient. In the case of NPV calculated from ratio B/C, the

[39] More about evaluation in the following chapters.

benchmarking value is then equal 1, i.e. values in the interval $(1; \infty)$ are considered efficient and values in the interval $(0; 1)$ are considered inefficient

Performing sensitivity analysis

Sensitivity analysis examines if, eventually how is expected cash flow affected depending on the change in factors. It also identifies the curtail factors that could influence the effectiveness of the project/policy. It is appropriate to perform the sensitivity analysis at least in the case of discounting to see how the chosen height of social discount rate influences the results of the analysis.

Making a recommendation where appropriate

It is not the aim of the CBA to make decisions; it lays down only recommendations for decision makers. Also, a summary of the all previous steps and assumptions should be provided in this step. It is useful to keep in mind, that NPV is just a predicted value and the circumstances can always change. Generally, the project with largest NPV, eventually B/C ratio, is considered as the most efficient when comparing more alternative projects/policies. When evaluating single project/policy, comparison with benchmarking value is in place (as mentioned previously).

2.2.2 Environmental CBA and its weak spots

CBA is currently a very widely spread method. It is popular among researchers and the decision makers due to straightforward logic and quite simple interpretations. CBA also become the prominent method of environmental evaluation in recent years. The field of the MWM is not an exception in that regard. Nowadays, is used to evaluate both whole WM policies and the individual WM systems (see e.g. Folz 1995; Weng and Fujiwara 2011; Damigos et al. 2016; Chifari et al. 2017) The majority of CBA MWM studies is centered around recycling, according to Lah (2014).

In the same time, the CBA is specifically required as a *"basis for decision making on the co-financing of major projects included in operational programmes (OPs) of the European Regional Development Fund (ERDF) and the Cohesion Fund"* (EC 2014), which also contributed to the spread of this method.

However, CBA has its own weak spots also, hence it is often a subject of criticisms. Pickin (2008) in his review of CBA solid waste recycling studies identifies five critical areas of this type of analysis. The examined studies proved to be inconsistent with each other in the type of impact and their evaluation, differed significantly in the following five aspects:

- the types of environmental impact and their valuation,
- the relevance of upstream externalities.
- whether there is a scarcity externality,
- the economic significance of householder efforts and
- the need to drive towards long-term sustainability through eco-restructuring

Pickin (2008) argues that CBA can be often used as a manifestation of ideology rather than the means of seeking the true state of the matter. He suggests CBA better be used with *"multiple levels* *of information, disaggregated environmental data, range values, sensitivity analysis, itemisation of excluded or unvalued elements, and valuation by multiple methods."*

Even more radical are Ackerman and Heinzerling (2002) in their critique. In their view, the flaws in the methodology of CBA exceed by far the potential benefit (if there is any) when trying to use it in order to evaluate environmental goods. They refer especially to the morality of such an evaluation. They object against the idea of monetary evaluation of environmental goods itself; they alert about trivializing future by discounting. CBA according to them proposes an increase in inequality while it does not distinguish who pays the costs and who earns the benefits. They also question transparency and objectivity of CBA. Finally, they also point out some other common practical problems of CBA, e.g. ignoring of factors that are inestimable or overstating costs or benefits.

Hwang (2016) in his paper, on the other hand, attempts to answer criticisms of CBA and defends its use for evaluation of environment, health, and natural resource policy. He focuses on the most discussed problem areas, i.e. monetary valuation, discounting and inequality. He argues that critics are not convincing enough to completely reject CBA. The philosophical and moral aspect of the critiques is not relevant because the rationale is completely different from assumptions of economic analysis. It is also possible that evolving alternatives of CBA will be constructed in the future. Therefore it will better to pursue methodological improvement of this method rather than its complete rejection. He further emphasizes, that CBA estimate plays an advisory role and the final decision is still always up to decision makers.

In the context of this thesis, we would like to address at least the most discussed weak areas, as suggested by literature: *evaluation problem* and *discounting problem*.

Evaluation problem

The CBA must take all possible costs and benefits into account. It is not an exception, that big part of these does not have a direct monetary value. CBA as a quantitative method, however, requires these to be also expressed in monetary terms. Therefore, quite a number of techniques how to evaluate the goods/services have been developed over the time.

For us, in this thesis, it creates a problem, which of the evaluation techniques is the most appropriate in our context. The careful identification of relevant costs and benefits is needed, as well as identification of stakeholders in order to choose the most fitting evaluating method. Therefore, a special chapter of this thesis is dedicated to the valuation of environmental goods/services.

Discounting and the social discount rate

CBA often aims to evaluate projects extended into more time periods. Discounting is a technique used to elicit future monetary flows in current values, and it is an important subject of CBA critiques. It is the tendency to undervalue the future that seems to a lot of authors problematic. Also, the aspect of uncertainty is here, while we the discount rate is not a static variable. We cannot know what discount rate will be relevant in the future when the monetary flaw occurs.

In the economic CBA, it is required to use the social discount rate for discounting. The selected value of the used rate can obviously influence the resulting value estimated by CBA. That is why choosing appropriate social discount rate is crucial in the CBA. The appropriate height of the social discount rate still remains the subject of the discussion (see e.g. Moore et al. 2004; Evans and Sezer 2005).

In this thesis, however, the annual ex-post CBA will be performed, in that case discounting in unnecessary. Therefore, we will not discuss the discounting problem any further.

2.3 Valuation Methods of Environmental Services

Every quantitative analysis (including especially CBA) requires of course to quantify the value of individual inputs and outputs. Valuation of environmental goods is however quite problematic mostly due to the non-existence of competitive market and thus also market prices as directly observable monetary values. Besides, the presence of other market failures, such as externalities and imperfect competition is also common. Therefore, alternative techniques and methods on how to estimate demand for environmental good must have been invented: *non-market valuation methods*[40].

The underlying principle of non-market valuation methods is a willingness to pay/accept. Unlike marketed goods whose willingness to pay is easily observable in the form of market price, in the case of non-marketed goods and services the value needs to be elicited a little bit differently (Pearce and Howarth 2000). We do not necessarily need to know market prices in order to estimate individual demand for environmental good/service. The fact that people are willing to pay for some good is reflected in demand for the good alone. When knowing the demand, we can also estimate consumer surplus hence perceived utility from the environmental good. Market demand is after that derived approximately as the sum of individual demands of consumers concerned (Dvořák et al. 2007). The total value of environmental good should correspond with a change in a total benefit of society, i.e. the sum of change of benefits of individuals.

There exist two interchangeable perspectives to evaluate non- market goods: *marginal willingness to pay* (hereinafter WTP) and *marginal willingness to accept* (hereinafter WTA), both can be found in two additional variations: *equivalent variation* and *compensating variation*. Equivalent variation indicates the willingness of subject to either accept certain improvement to her state or pay for certain perceived damage done to her due to the environmental good consumption. Compensating variation, on the other hand, indicates willingness either to pay when improvement occurs or accept compensation when damage is done (Melichar and Ščasný 2005). Differences between these two variations are also presented in Table 6.

[40] Other approaches then eliciting WTP/WTA by non-market valuation methods to derive monetary value of environmental degradation, damage or benefits also exist. Among others for example market and quasi-market prices, juridical value (i.e. monetary value is set by legislation) and expert opinion or judgment (Melichar and Ščasný 2005).

TABLE 6
DEFINITION FEATURES OF WTA AND WTP

	Equivalent variation	Compensating variation
Utility increases	*WTA*	*WTP*
Utility decreases	*WTP*	*WTA*

Source: Haab and McConell (2002, p. 7)

By definition, the monetary/compensating value derived using WTP and WTA should be identical. In practice, however, we can observe a systematic difference when WTA approach tends to acquire higher values then WTP approach, especially when using stated preferences methods (see more about stated preferences methods in following subchapters). Differences between values of WTP and WTA may also be caused by loss aversion, which is a known phenomenon of the behavioral economics. In a nutshell, people do not compare utility from the situation before and after the change, but rather net relative change to status quo. Another reason for differences between WTP and WTA can be caused by the fact, that it is not easy to substitute the environmental good with alternative provided at the competitive market, because the alternative often does not even exist (Haab and McConell 2002).

Non-market evaluation methods of environmental good are built on a base of methodological individualism and welfare economics theory. Which means that total economic value is always derived from individual preferences when using these methods (Melichar and Ščasný 2005). Simultaneously, the monetary value is derived from a change in individuals' utility evt. welfare (Haab and McConell 2002). The total value (hereinafter TEV) of environmental good consists from several components whose overview is presented in Table 7. We would like to point out the division into *Use value* and *Non-use value*. Notice, that value of some environmental good can be derived just for simple existence of this good (e.g. biodiversity). This division is important to keep in mind while some non-market valuation methods (i.e. revealed preferences method) are able to evaluate only the use value[41].

[41] See Figure 5

TABLE 7
THE TOTAL ECONOMIC VALUE AND ITS COMPONENTS

Total Economic Value						
Use Value				Non-use Value		
Current use			Option	For others		Existential
Primary (direct)	Secondary (indirect)	Unobserved (function)	Potential future direct/indirect use values	Altruism	Legacy	
• wood • feed • fuel • medicines • recreation	• wild • scenery • relaxation • biodiversity	• climate • soil quality • retention (floods) • weather (storms) • hydrology	• biodiversity •conservation of species and habitats • recreation • scenery • wild	• own children • family • other people	• to grandchildren • to future generations	• biodiversity • species / habitats • ecosystem

Source: Dvořák et al. (2007), Pearce and Howarth (2000)

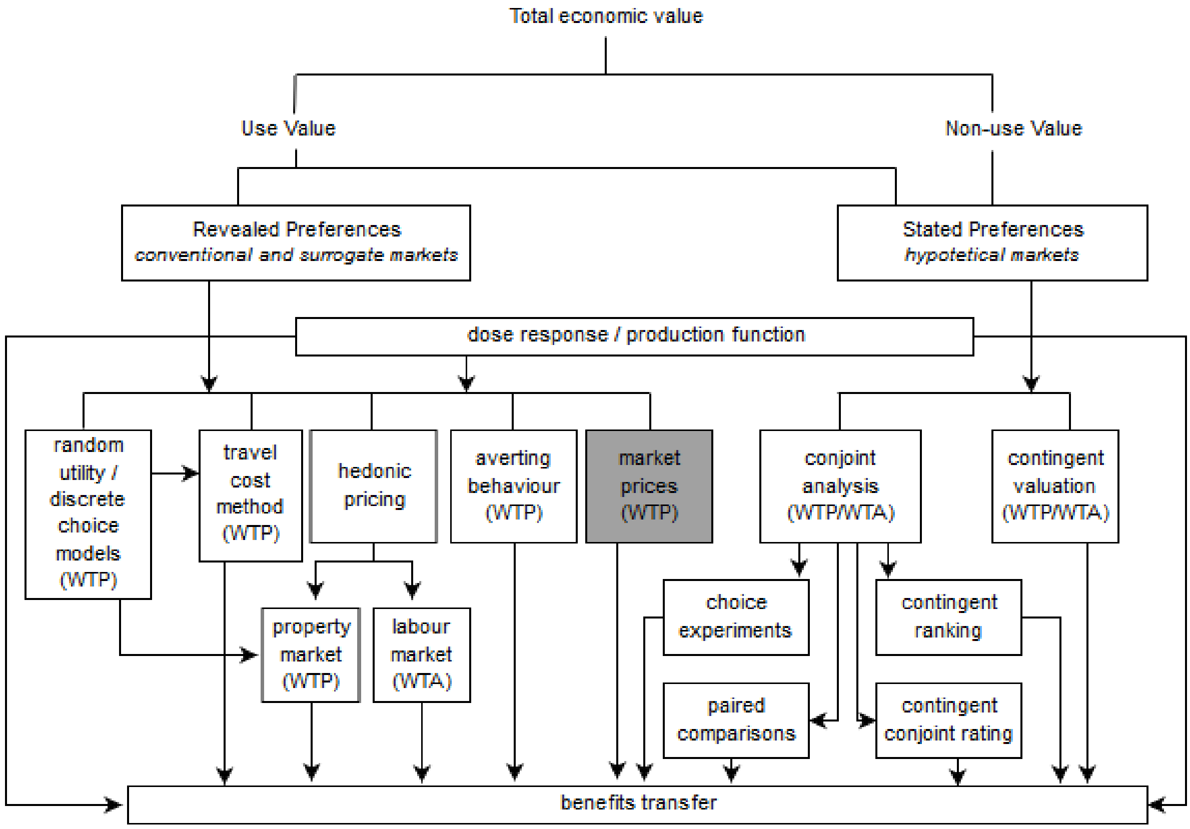
There exists quite a number of non-market valuation methods to estimate TEV and at the same time the demand for environmental goods/services. Various authors, who researched non-market valuation methods, use different taxonomies of these methods[42]. In this thesis, typology according to Pearce and Howarth (2000) will be used. This widespread typology uses a division of methods according to two different approaches: *revealed preferences* vs. *stated preferences techniques*. In Figure 5, the scheme of methods further discussed in this thesis is presented, together with their capacity of estimating WTP and/or WTA. In the next subchapters, the brief overview of non-market valuation methods is presented.

In this thesis, we will be using just non-market valuation methods to evaluate the MWM in the Czech Republic. Even though some could argue that MWM does not fit literally into the category of environmental service, we observe that key feature is common: the competitive market at the level of municipalities does not exist here resp. the market is imperfect by setting administrative monopoly. Additionally, we can also observe further market failures relating to waste management. The typical example is externalities, e.g. negative externality of illegal dumping: person, who illegally throws his waste in nature does not bear all the costs of this action by himself. These costs[43] will affect the entire community.

[42] For more detailed overview of taxonomies of non-market valuation methods see for example Melichar and Ščasný (2005, pp. 7–8).

[43] For example: air pollution (smell, harmful particles etc.), water contamination, soil contamination, damage of the landscape appearance, etc.

FIGURE 5
TYPOLOGY OF VALUATION METHODS AND TOTAL ECONOMIC VALUE



Source: Pearce and Howarth (2000), adapted from Melichar and Ščasný (2005)
Note: Market prices, as only Market Valuation Method in this diagram is highlighted in grey. All other methods in this diagram fall into the category Non-market Valuation Methods and as such are briefly introduced in following subchapters

2.3.1 Stated preferences methods

Since for a number of environmental goods and services competitive market, for the most part, does not exist, different methods of valuation must have been constructed in order to evaluate it. Instead of the actual market, we form a so-called *constructed market* (Dvořák et al. 2007). Value of environmental good or service is then estimated from this newly constructed market. There exist two types of such constructed market: *experimental* and *hypothetical* (Kolstad 2000).

In the case of the experimental market, researcher construct market with all elements as the real market would have, only in artificial conditions of the experiment. Experiment participants are then allowed to enter this market, they to perform choices and transactions according to their preferences. After closing the experiment, market demand and subsequently also price (i.e. value) is estimated similarly as in case of the real market. Two different types of experiments can be performed: a laboratory experiment[44] or field experiment[45] (Dvořák et al. 2007).

The principle of valuation using hypothetical markets is a direct survey among respondents. They are asked about their preferences; how would they act if there existed a market for certain environmental good or service (i.e. their WTP or WTA).

On the other hand, some problems are associated with stated preferences methods. Melichar and Ščasný (2005*)* name, for example, strategic and protest bias*,* design bias, payment vehicle availability bias*,* the embedding problem hypothetical bias or compliance bias.

The two methods which use the principle of stated preferences[46], *contingent valuation method* and *conjoint analysis*, are presented in subchapters below.

Contingent valuation method

The more widespread from stated preferences methods is the contingent valuation method (herinafter only CV). It is used for the evaluation of environmental goods since the 1960s and very popular in academic research to this day (Ferreira and Marques 2015). Expansion of CV is associated with more and more frequent use of CBA for the assessment of public policies and projects (Dvořák et al. 2007).

The core of CV is the collection of primary data whether via survey or experiment. Since the more common form is gathering data by a questionnaire, we will focus in the following paragraphs more on this method. CV survey usually consists of 3 parts: firstly, the subject of the questionnaire (i.e. the environmental good/service we want to evaluate) is introduced and explained to respondents. Secondly, respondents are asked to express their WTP (evt. WTA) for this good/service[47]. Finally, in the third part researchers reconnoiter socio-economic characteristics of respondents. Obtained data are then analyzed, and the average WTP/WTA value is calculated (Melichar and Ščasný 2005).

It seems like discussion keeps running between critics (e.g. Diamond and Hausman 1994; Hausman 2012) and advocates (e.g. Hanemann 1994; Carson 2012; Haab et al. 2013) of this method about its credibility and lot of arguments and contra-arguments has been made. CVM indeed carries a number of issues, that we do not discuss any further in this thesis[48]:

The CV is also often used for evaluation of MWM and recycling systems (e.g. Jakus et al. 1996, Lake et al. 1996, Tiller et al. 1997, Berglund 2006, Ferreira and Marques 2015). Nevertheless, CV is more suited for case studies made for each municipality separately, which is not aimed of this thesis. We would like to focus more on the valuation of waste separation systems as a whole, to

[44] In the case of laboratory experiment all goods services and transactions are fictional.

[45] In the case of field experiment real transactions on the artificial constructed market take place.

[46] I.e. use constructed markets for valuation.

[47] Researchers may use number of different techniques how to elicit the value of WTP/WTA. Haab and McConell (2002) list four basic approaches: open-ended CV, bidding game, payment cards and dichotomous/discrete choice.

[48] For detailed overview of CV biases see e.g. Melichar and Ščasný (2005)

calculate an average value (i.e. benefit of waste separation) for a bigger area. Subsequently, this method carries so many additional potential biases that we decided not to use CV in this thesis.

Conjoint analysis

Conjoint analysis (from now on only CA)[49] avoids the problem with stated value by laying down hypothetical choices or trade-offs from which people choose. Their choices then help to determine demand and subsequently also the value of particular environmental good or service (UN et al. 2003).

CA is by its method very similar to CV meaning both methods are built on gathering primary data, i.e., questioning respondents about their preferences. But unlike CV, CA does not ask respondents directly about value in monetary terms. Instead, it presents alternatives of environmental goods/services with different groups of characteristics to respondents at a given (hypothetical) price (Melichar and Ščasný 2005). Respondent then chooses from these according to his/her own preferences under premises that consumers' satisfaction is not derived from the environmental good itself, but rather from *"the attributes or features that the goods provide"* (Dvořák et al. 2007).

CA can be approached in a number of different formats. In fact. CA is actually not one established method with the strictly given procedure, but rather a couple of similar approaches which involve ranks or matches between given alternatives. Dvořák et al. (2007) list four most common formats of CA being:

- *choice experiments* (respondent chooses between an introduced set of alternative options)
- *contingent ranking* (respondents ranks an introduced set of alternative options from most to least desirable)
- *contingent/conjoint rating* (respondent rate or grade alternatives at a given range)
- *paired comparisons* (the respondent compares between two alternatives while rating the preference strength at same range for both)

To that UN et al. (2003) add *self-explication* and Melichar and Ščasný (2005, p. 19) broaden the formats of CA to *"various similar techniques using choices, ranks or matches."* In each of the cases previously mentioned, respondents' choices are subsequently statistically analyzed, and relative values are estimated for all attributes. The result of this method can be either the rank of attributes or monetary value (WTP) of attributes, under the condition that one of the initial characteristics is a monetary price.

Unlike in the case of CV, the WTP is estimated indirectly here. Thus CA does not carry some problems occurring in case of CV (Dvořák et al. 2007). CA also allows capturing more dimensions of environmental policies thanks to the evaluation of individual attributes, and it provides bigger informative value to respondents. On the other hand, when estimating WTP same ambiguities apply for both CV and CA (UN et al. 2003) while it is more demanding on respondents cognitive abilities.

[49] Techniques of conjoint analysis fall also under the term "choice modelling" (Dvořák et al. 2007)

According to SEEA-2003 (UN et al. 2003, p. 408), use of CA is convenient especially for "*policy decisions between actions with different impacts on natural resources or environmental services where a set of possible actions might result in different impacts on natural resources or environmental services."* According to this definition, CA might be a suitable method for evaluation or ranking different MWM systems (e.g., deciding between systems tending more to recycling vs. incarceration vs. landfilling). However, CA is (similarly as CV) in principle better suited to case studies. Therefore, CA will not be used as a valuation method in this thesis either.

2.3.2 Revealed preferences

Methods of revealed preferences, unlike stated preferences methods, are based on observation of real behavior in real markets. Since the market for good or service evaluated does not exist, these methods usually use other conventional or surrogate markets for evaluation instead (Pearce and Howarth 2000).

Usually, the consumption of environmental good is somehow tied to consumption of other, marketed, good. The real source of utility for the consumer is then consumption of a combination of these two as either substitutes or complements[50]. Revealed preferences methods use this fact by estimating the value of environmental good from observed market-based information. The preference for the environmental good is expressed through consumer behavior at markets with the influence of environmental factor in question. Practically, the preferences are revealed *"indirectly when individuals purchase marketed goods which are related to the environmental good in some way"* (Pearce and Howarth 2000)

Dvořák et al. (2007) distinguish between two types of methods in regard to revealed preferences: *hedonic methods* and *household production methods*. In the case of the hedonic method, the value is projected in the price of other common marketed good, i.e. it observes changes in the price of marketed due to changes in the quality of the environmental good. On the other hand, the household production methods are concerned with the combination of the environmental and marketed good that is consumed. The value is derived from this joint consumption because the combination of these two goods is the real source of the utility.

The revealed preferences methods are based on the actual decisions and behavior on the market, which is the biggest upside of these methods compared to stated preferences methods. We do not face the hypothetical bias here. Contrary revealed preferences methods could not measure (estimate) other than use value (see Figure 5). Non-use value of the environmental good cannot be expressed by these methods, and in the same time, a new level of the environmental good also cannot be evaluated by these methods[51] (Melichar and Ščasný 2005).

[50] For example, in the case of degradation of environmental good, people might choose to substitute its consumption with other marketed good or at least to mitigate damage by combining it with complementary protective means.

[51] I.e. when people do not have complete or sufficient information about the real state of the good or even experience with it.

Hedonic pricing method

Hedonic pricing method (from now on only HPM) essentially derives price of environmental good using another already existing market. It is based on the assumption, that the market value of the good reflects all its attributes, one of them can be particular environment good (Melichar and Ščasný 2005). An example may be the application of HPM at property market: every house has a number of basic attributes (area, number of rooms, age, etc.), but into the price also enter attributes of the environment (e.g. noise, air quality/pollution, proximity to nature, etc.). The task of the HPM then is to derive environment good demand function directly from property demand function.

HPM typically consists of two steps: First, this method estimates, how much of the price makes each attribute, especially desired environment parameter, i.e. what price difference it makes. Then second, it estimates consumers' WTP for improvement in the environment and subsequently calculate the aggregate value of environmental improvement (Pearce and Howarth 2000).

Let's see, if HPM could be used for valuing MWM, more specifically municipal waste separation systems. HPM is most often applicated on the property market or labor market (Dvořák et al. 2007). MWM system could certainly enter into the price of the property[52]. So, in principle, it would be possible to use HPM to derive demand for waste separation system in the municipality. However, only under the assumption, that system operates in only part of the municipality and not throughout the whole area[53]. This is usually not the case in the Czech Republic. Another reason why HPM cannot be used in this thesis is that we would like to examine the value of the waste separation system separately for each municipality[54]. The property market in such a small area would be unfortunately either too small to statistically examine or even non-existent at all.

Averting behavior

Next revealed method is averting behavior method. It is used mostly in the case of the presence of some kind of environmental goods degradation; some authors use the term *environmental bad* for it (Dvořák et al. 2007). This method assumes, that in case of degradation consumers either combine environmental good with marketed goods as complements (e.g. household water filters in case of bad quality of tap water) or even substitute environmental good with marketed one (e.g. bottled water in case of bad quality tap water) to mitigate degradations consequences and maintain the level of own consumptions quality. This is called *averting expenditure*[55].

The goal of averting expenditure for consumers is either to *"prevent an environmental impact, or prevent a utility loss by environmental degradation, or change of behavior to acquire greater environmental quality"* (Melichar and Ščasný 2005). In other word, if households aim to sustain their initial level of welfare, they are forced to change their market behavior accordingly, i.e. they

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[52] E.g. proximity to recycling collection points

[53] It is impossible to estimate the change in price caused by a parameter, when this parameter is same for all observations. The use of HPM would be suitable, when municipality does not use only one method of collection of separated waste. For example, it uses drop-off collection points in one part and kerbside collection in another. This scheme is often used in bigger towns. In this thesis it will be assumed, however, that every municipality uses one method only.

[54] …and then calculate average value.

[55] Terms preventive, defensive or regrettable expenditures can be also used (Melichar and Ščasný 2005).

spend on averting means[56]. Hence, in theory, the money spent on averting expenditure should correspond to the value of initial environmental change (i.e. environmental good degradation).

The biggest downside of averting behavior method is that it often gives underestimated values, if not used properly. All types of substitution relationships and effects must be taken into consideration as well as other aspects of consumers' behavioral responses, e.g. when households combine more than one type of averting behavior, when averting behavior brings other positive effects than just reduce initial degradation (Pearce and Howarth 2000), when averting behavior is influenced by other external factors (for instance by marketing campaign), etc. Additionally, underestimation may also occur if averting behavior is discrete rather than continuous choice[57]. Melichar and Ščasný (2005, p. 13) also point, that *"averting expenditures can rarely eliminate the impacts due to environmental degradation completely. Therefore, in the case of pollution, one should sum up averting expenditures and residual pollution costs in order to derive the total costs of pollution"*. On the other hand, this method provides theoretically reliable estimates, which are based on actual expenditure, and it is not as demanding for data collection as some other methods.

Also with averting behavior method, we find cases when it was applied to WM (e.g. Smith and Desvousges 1986). However, in such cases, WM plays the role of adverting expenditure. Same would apply if we tried using this method in this thesis. Unfortunately, the waste municipal waste separation system it is the very environmental service we are attempting to evaluate in this thesis, hence cannot play both roles: the evaluator and evaluated. Subsequently, the non-existence of a competitive market for waste separation in Czech municipalities makes use of averting behavior method impossible in our case.

Travel cost method

The travel cost method (hereinafter TCM) applies when traveling and associated expenditure is needed in order to consume the environmental good. It is typically used for evaluation of site-specific good, such as recreational sites. The principle of this method lies in fact, that people must incur some costs when they want to visit and exploit the environmental good and subsequently increase their own utility from its consumption. Total traveling costs do not consist just from the costs of transportation, but also from possible entry fees, on-site expenditures and time spent traveling. The total costs visitors pay in order to visit (i.e. to subsequently consume) the environmental good are the proxy for the value of this good (Pearce and Howarth 2000).

There are two types of TCM models, according to Parsons (2003): a *single site model* and a *random utility model*. The latter one can be alternatively called a *multiple site model* (Dvořák et al. 2007).

[56] Melichar and Ščasný (2005) describe (and illustrate on tap water degradation example) three ways, how consumer can avoid of negative impacts of environmental change: *"1) buying durable goods (e.g. complement tap water with water filters), 2) buying non-durable goods (e.g. substitute tap water with bottled water) and 3) changing behavior/routines to avoid exposure (e.g. boiling water for cooking or drinking)"*.

[57] See durable good's purchase or change of behavior in footnote nr. 40.

- *Single site model* (SSM): this model estimates demand for one specific recreational site, i.e. environmental good. The recreational demand is in this case function of trip costs and socio-economic variables, while a number of visits plays the role of the dependent variable. When the demand is known, first individual consumers' surpluses are calculated to make the aggregate surplus corresponding with the total value of the environmental good.
- *Random utility model* (RUM): This method allows to evaluate the benefits of individual characteristics of the environmental good or even the change in those characteristics (i.e. quality of the good). A site utility is a dependent variable in this case – as a function of travel costs and characteristics of the site. Pearce and Howarth (2000) earmark this method as a separate method, therefore, the logic of RUM will be presented in the next subchapter.

We can further distinguish between two models by the method of empirical estimations execution: *individual* vs. *zonal TCM* (Dvořák et al. 2007; Melichar and Ščasný 2005).

- *Individual TCM* (ITCM): the individual demand of environmental good is constructed from actual visits of individuals and their costs, while determined by other factors (e.g. socio-economic characteristics, availability of substitutes, the perception of environmental characteristics, recreational experience, etc.). When knowing individual annual consumer surplus, we can estimate the total annual consumer surplus by multiplying by a number of visits to calculate the proxy value of the site.
- *Zonal TCM* (ZTCM): unlike ITCM, this model estimates using all potential visitors. They are not, however, judged as individuals, but they are sorted into zones according to from where they come. The zonal annual consumer surplus is estimated from zonal travel costs and socio-economic characteristics for each zone separately.

The biggest downside of TCM is the fact that this method can estimate no other than the use value of the good concerned. This is due the necessity of active participation of visitors, i.e. it is assumed that the good has the value derived only for those who visit. TCM is also very demanding in respect of data requirements (Pearce and Howarth 2000). This makes TCM a method that is usually only used on specific types of environmental goods, where data about visits are available, e.g. outdoor recreational sites.

The waste separation is clearly a service that cannot be considered as anything close to outdoor recreation. Therefore, TCM seems to be impossible to use in respect to MWM evaluation.

Random utility models

The method where the value of environmental good is estimate using consumers choice between two and more alternatives is called the random utility model (hereinafter RUM), eventually discrete choice models. Consumer faces the choice between alternatives of very similar or the same good/service with different environmental parameters or features and consumers' utility from it. The principle of this method is an assumption that *"an individual derives utility by choosing an alternative"* (Walker and Ben-Akiva 2002). According to RUM, the utility from the choice can be explained with a function of their characteristics (Pearce and Howarth 2000).

In the same time, the very purpose of this method is to evaluate individual parameters of environmental goods. This is a big advantage comparing to, e.g. single site TCM, which can evaluate the good only as a whole. When the market price is not known, RUM is often used in combination[58] with another valuation method (typically TCM).

Pearce and Howarth (2000) illustrate the use of RUM on the example of transportation choice (more expensive, but faster taxi vs. cheaper but slower public transportation) and the choice between tap and bottled water (bottled water is more expensive but associated with better quality and vice versa). The example of different alternatives for waste management is also applicable in this context. Let's assume that consumers choose only between 2 alternatives: they can either participate in the system of MWM for just mixed waste and MWM for just separated waste. The difference in the market prices of these two should then correspond with the difference in utility for the users (subsequently with aggregate value), particularly the environmental awareness.

However, the price for MWM in the Czech Republic is not determined by the market (i.e. by consumers' choices and preferences) but by political decision of the local authorities. Thus, in the case of this thesis, mere RUM cannot be used for a reliable mean of evaluation, just only in combination with another non-market valuation method.

2.3.3 Time as an evaluating instrument

None of the methods explained above seem to be "perfect fit" for our case, namely evaluation of municipal waste separation systems. Therefore, we decided to approach non-market valuation from an alternative perspective, while still following the same logic as WTP / WTA. As already explained, the value in the non-market valuation methods is derived from the amount of money the people are willing to spend in order to consume the environmental good or service. However, the money is not the only possible instrument of evaluation[59]. We consider the information how much time people invest in the activity as essential indicative of their preference and subsequently the value they attribute to this activity. We could say, that this *willingness to engage* is a direct alternative of WTP / WTA, while time spent with this activity exhibits relevant features of economic good, i.e. it is rare[60] and its consumption increases utility.

In this thesis we will be using, in fact, a modified TCM method: instead of counting for all the traveling costs we consider *only time consumption costs* as a proxy value for the perceived benefits of the waste separation[61]. In other words, the time spent on the waste separation acts here as a proxy value for the benefits evaluation. The biggest upside of this approach is in our perspective the fact, that this simplified TCM is, as a revealed preference method, based on actual observed behavior.

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[58] Or, as a modification, eventually an extension of another valuation method.

[59] Even though perhaps the most easy and appropriate one in other cases.

[60] An individual can spend only limited amount of time units on the activity per given time period, in another words: there is a time constraint for every activity.

[61] It is assumed in this thesis, that people handle the matter of waste separation only by walk, hence waste separation induces no other "travel"costs than time. We are aware that some people do commute the collection points by car, but this fact will be considered as an exception that is not included in our estimations.

Some could, of course, argue, why to evaluate through time spent when it might be an unnecessary complication of the value estimation process. We argue on the other hand that it opens more opportunities for evaluation especially when it is appropriate to use revealed preferences for evaluation while the fitting competitive surrogate markets cannot be found. In that case, evaluation using time as a proxy value of preference is an important intermediate step in order to estimate the resulting value.

It will be assumed in this thesis, that individuals can trade their time for the environmental service in a similar manner as they would trade money for it. Our assumptions are based on DeSerpa (1971), who in his "theory of time" puts emphasis on time consumption constraints. According to him, every activity always requires a certain time investment. It is then the matter of individual preferences and choice if a person wants to invest more or less time in it than required. When we apply this claim to our topic (i.e. waste disposal), we could conclude that while there is indeed certain time required for household's waste disposal, waste separation, however, takes considerably more time and effort. Therefore, those who engage in waste separation express their preference and attribute value to this activity at the same time. In the upcoming part of this chapter, we will talk a little about the *evaluation of time* and its theoretical background on which the model in this thesis will be based.

The time dimension as a significant factor in decision making seemed to be ignored for the most part and the long time by economists. It was until Becker (1965) included the time constraint into the theory of choice. His theory of the allocation of time was the pioneering work in this regard and at the same time became the foundation for the evaluation of non-working time. His model provided at the time a new perspective to the allocation of the time among activities by introducing the costs of forgone earnings (i.e. opportunity costs) into the consumer theory by including the time component into the utility function. The substitutional relationship between consumption of goods (i.e. working time) and leisure (i.e. non-working time) then entered the economic textbooks. DeSerpa (1971) developed a more general model of time that included not only money but also a time constraint[62]. The utility function of any activity consists of both, commodities and time consumption.

So far, the value of the non-working time is considered to be equal to the opportunity costs of work time, i.e. to the wage rate. Becker's theory, however, carries a couple of drawbacks which are gradually addressed by later authors. Namely the assumption about the flexible working hours that can be chosen freely by workers, which was rather unrealistic. Tipping (1968) even objects to the setting value of leisure time arbitrary at the wage rate while arguing, that the chosen method of evaluation can significantly influence the resulting value. This could be the reason why later it became a common practice to use only a fraction of the wage rate in order to evaluate non-working time (Feather, Shaw 1999). For example, Owen (1971) argued exactly that (i.e. the value of leisure time equals less than average hourly wage rate) and then conducted an empirical analysis that confirmed his claims. Quite contrarily Larson (1993) argues in his study that the entire wage-rate is an appropriate shadow value for leisure time, more specifically the wage rate after tax.

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[62] Becker's model assumed a single resource constraint, since time is considered to be convertible into goods and vice versa.

Another suggested drawback of the initial Becker's theory is the fact, that the dependence of this model in wage-rate makes it unrealizable to evaluate the value of the leisure time for non-wage workers and unemployed. Feather and Shaw (1999) propose a different approach, namely using a hedonic method to evaluate time. Also, Verbooy et al. (2018) try to overcome this problem, this time by using contingent valuation. Both of these studies find that resulting value estimated by the proposed method differs from wage-rate.

The time evaluation has a particular impact on transportation (e.g. Tipping 1968; Jara-Díaz et al. 2008) and recreation studies (e.g. Feather and Shaw 1999). In transportation, time savings are considered to be a significant benefit for travelers.

From the perspective of this thesis, an approach proposed by Wang and Li (2009) is especially interesting. They aim to evaluate the households' time and money allocation. They developed a household-based model of time allocation and proposed a wage-rate of domestic helpers as a proxy value of time.

In this thesis, we are inclined to the approach based on Becker, for several reasons. Primarily we think, that wage-rate approach is better theoretically grounded then proposed alternatives. This approach to the evaluation of time is also accepted by the wide economic public. Further, in this thesis we will not proceed with our analysis from the strictly individual point of view. Instead the unit of our analysis will be a municipality. This means that all variables in our analysis will be municipality-specific (i.e. either aggregate or average of individual variables) rather than individual-specific. Hence, we believe that in the average form described drawbacks will not play as significant role. Therefore we will build our analysis on Larson (1993) and assume in this thesis, that all wage rate after tax is a suitable proxy of the value of non-working time.

3 DATA

For the purposes of this thesis data about municipal waste separation was gathered. The existing databases, unfortunately, do not maintain a database of data specifically tied to waste separation alone. For that reason, the gathering of primary data was needed, complemented by data from the Czech Statistical Office (hereinafter CZSO) database.

It is obvious, that gathering data from all municipalities in the Czech Republic to perform CBA on all municipalities would be too time-consuming. For that reason, the stratification sampling was done: all municipalities (excl. Prague[63]) in the Czech Republic were assigned to 13 groups, which correspond with Czech *Administrative Regions*. Administrative regions in the case of Czech Republic correspond with NUTS 3 category, i.e. a number of inhabitants in the region is between 150,000 and 800,000.

Subsequently, the random sampling of 30 municipalities across regions were sampled and contacted via e-mail (i.e. 390 municipalities in the total). In this e-mail, the representatives of each one of the sampled municipalities were reached and asked to fill in a questionnaire (for the English transcript of the questionnaire see in Appendix 1). Questions about municipal waste separation were asked and annual data from the period from 2011 to 2017 were requested. Two alternatives of the same questionnaire were provided to the municipalities to use the more convenient one: the excel and the online version.

In the total, 45 municipalities were willing to cooperate by sending the filled questionnaire back. Out of these 45, 12 questionnaires were filled incompletely in regard to quantitative data and therefore could not be used for the purposes of quantitative analysis and will be included only in the review of open questions.

The variables emerged from the CZSO's data are listed in Table 8, together with their description.

TABLE 8
BASIC DESCRIPTIVE VARIABLES THAT DEFINE AND DISTINGUISH INDIVIDUAL STATISTICAL OBSERVATIONS

Variable	Variable type	Units	Description
basic descriptive variables characterizing the municipality			
Municipality	nominal	**-**	**Designation of the municipality by its name**
ZUJ	nominal	-	Designation of the municipality by unique ZUJ code
Region	nominal	-	Variable characterizing region
Year	ordinal	-	**Variable characterizing time period**

Source: Author, CZSO (2018a)

[63] Prague with over a million inhabitants is by far the biggest municipality and also only metropolis of the Czech Republic. In the same time, is seem that MWM report diametrically different values from the rest of the Republic (see Table 2). Including Prague into our analysis could potentially to divert results from reality, therefore it was beforehand decided not to include Prague in our analysis.

The data for the purposes of this thesis was gathered from multiple sources. Apart already mentioned questionnaires that gathered primary data directly from the municipalities, the CZSO database was also used as the source of data.

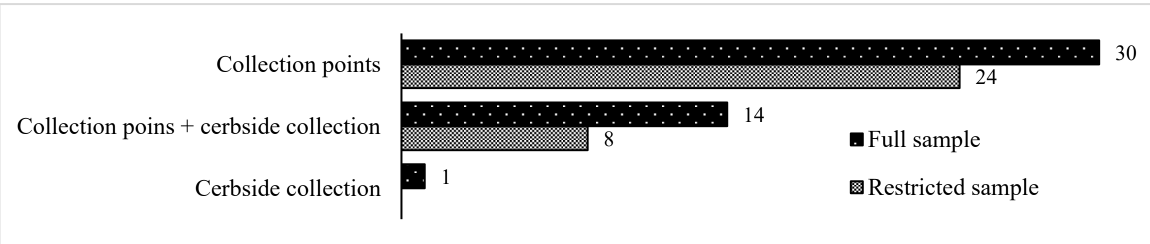
3.1 VARIABLES RESULTING FROM PRIMARY DATA PROVIDED BY MUNICIPALITIES

The data, that could not be obtained any other way, must have been acquired directly from the municipalities. These are data that characterize the nature of the waste separation systems in each individual municipality. In the total, two open questions, six closed questions and filling in 7 types of quantitative data were asked in the questionnaire.

Open questions were asked in order acquire information about perception of municipal waste separation by the municipalities alone. The answers are naturally not included in the dataset and do not formulate any of the variables for the quantitative analysis. These answers will be used just for the brief review.

Other answers were used in order to create a dataset for the purposes of further quantitative analysis. Because not all municipalities filled in properly quantitative data in the questionnaire, we include in the resulting dataset only those who did. Hence we restrict our sample by excluding in the end 13 municipalities from the initial sample. One more municipality (municipality Bánov) was excluded additionally: it was the only municipality with the waste separation system that does not use the collection points. The frequency of each observed systems in both samples is presented in Figure 6.

FIGURE 6
WASTE SEPARATION SYSTEMS USED BY MUNICIPALITIES IN THE SAMPLES



Source: Author, based on data by municipalities

The resulting sample then includes in the total 32 municipalities from the whole territory of the Czech Republic and the data about their waste separation across seven periods. Altogether it makes 224 observations[64] in the dataset. Since we use data from multiple time periods, our data are organized into the panel. However, we do not aim to examine time factor any further, we include multiple periods especially to exclude any extreme or unusual values that would influence the results. Using data obtained from this sample, ten additional variables were created. The list of variables resulting from the information provided by the municipalities is presented in Table 9.

[64] 52 of them are, however, incomplete.

TABLE 9
VARIABLES RESULTING FROM THE QUESTIONNAIRE

Variable	Variable type	Units	Description
System	nominal	-	Waste separation system used in the municipality; 1=collection points, 2=Collection points + curbside collection
Coll_point	quantitative	pcs	Number of collection points in the municipality
SMW production	quantitative	t/year	Production of separated municipal waste
C_SepW[65]	quantitative	CZK/year	Municipal costs of waste separation
EKOKOM	binary	-	Involvement of the municipality in the eco-com system; 0=NO, 1=YES
R_EKOKOM	quantitative	CZK/year	Income (revenue) from EKO-KOM company
SRM_sale	binary	-	Involvement of the municipality in the sale of secondary raw materials; 0=NO, 1=YES
R_SRM_sale	quantitative	CZK/year	Revenues from the sale of secondary raw materials
IMC	binary	-	Intermunicipal cooperation; 0=NO, 1=YES
Motiv	binary	-	Use of motivation instruments for waste separation; 0=NO, 1=YES

Source: Author, based on data provided by municipalities

3.2 VARIABLES RESULTING FROM CZSO DATA

The data that could be acquired other way than direct asking municipalities were primarily acquired this other way. This includes data that are not directly linked to the municipal waste separation. These data were acquired from the CZSO database for the purposes of our thesis. The three more variables were created by using CZSO data and added into the dataset (see following Table 10):

TABLE 10
VARIABLES RESULTING FROM THE CZSO DATA

Variable	Variable type	Units	Description
Population	quantitative	-	Number of citizens in the municipality
Area	quantitative	km^2	The area of the cadastral territory of the municipality
Wage_BT	quantitative	CZK/month	The regional average wage before tax

Source: CZSO (2018a; 2018c; 2018d)

[65] The information about municipal cost of municipal waste separation was initially divided into 2 components: *collection and transport costs* and *costs of other treatment of the separated waste*. Municipalities, however, in most of the cases do not maintain a database of separate costs regarding waste separation. This mean that for the purposes of this thesis we merge these two components into one category of *overall costs of waste separation*.

3.3 DESCRIPTIVE STATISTIC OF THE VARIABLES

The above-described variables create together with the individual observations a dataset with a total number of 224 observations and 14 variables, the panel then includes 32 cross-section units and 7 time periods.

The quantitative variables (i.e. population, area, average monthly wage before tax, number of collection points, total annual production of separated waste, total annual costs of municipal waste separation, revenues from EKO-KOM company and revenues from sale of secondary raw materials) together with categorical variables (i.e. year, system of municipal waste separation, involvement in EKO-KOM system, involvement in secondary raw materials sale, involvement in inter-municipal cooperation and presence of motivation means within municipal waste separation system) are listed in the Table 11 together with their descriptive statistics.

TABLE 11
DESCRIPTIVE STATISTICS OF DATA VARIABLES

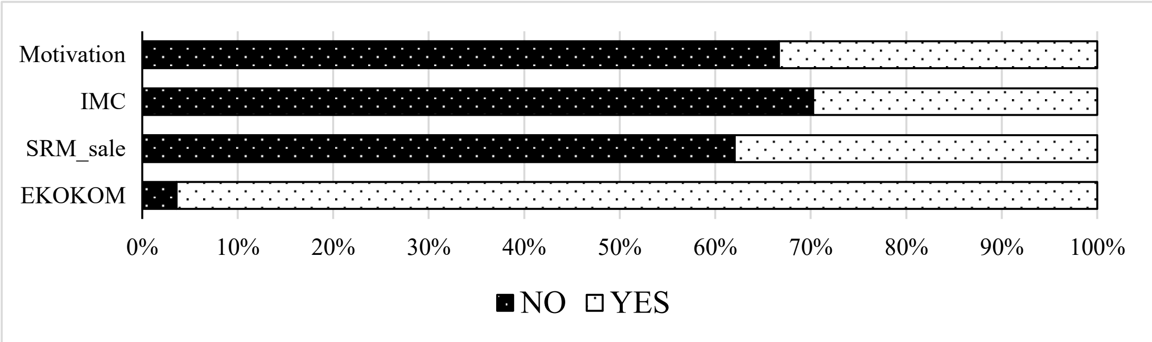
Variable	Number of observations	Mean	Standard deviation	Median	Min	Max
Time period variable						
Year	224	2014	2.0045	2014	2011	2017
Quantitative variables characterizing municipality and its waste management						
Population	224	10,087.00	22,461.00	927.50	43.00	93,801.00
Area	224	24.04	20.91	21.39	1.33	105.69
Wage_BT	224	23,700.00	1,849.80	23,302.00	20,752.00	29,917.00
Coll_point	197	61.198	188.69	8.0000	1.00	1,326.00
SepW_production	180	313.81	723.53	42.50	1.00	4135.50
C_SepW	179	1,098,228.79	2,427,140.22	274,071.00	7,000.00	18,453,298.00
R_EKOKOM	187	709,155.79	1,953,803.19	89,500.00	0.00	14,037,436.00
R_SRM_sale	192	12,929.09	42,895.35	0.00	0.00	336,005.00
Categorical variables describing municipal waste management system						
SWMsystem	220	1.2545	0.4366	1.00	1.00	2.00
EKOKOM	195	0.9641	0.1865	1.00	0.00	1.00
SRM_sale	195	0.3795	0.4865	0.00	0.00	1.00
IMC	195	0.2974	0.4583	0.00	0.00	1.00
Motivation	195	0.3333	0.4726	0.00	0.00	1.00

Source: Author
Note: missing values were skipped

For the categorical variables, the descriptive statistics does not have the proper informative value. Therefore, Figure 7 was included below, to illustrate the distribution of binary variables in the sample. The distribution of the categorical variable *SWMsystem* was already previously illustrated in Figure 6.

FIGURE 7

THE DISTRIBUTION OF CATEGORICAL VARIABLES IN THE SAMPLE



Source: Author

4 ANALYSIS

Now we proceed to the analysis of the collected data. We would like to primarily analyze the efficiency of the specific service that the municipality provides, i.e. waste separation. For that analysis, the CBA will be used. This method of analysis will be then complemented by two more analyzes, namely the review of the open questions of the questionnaire and also the regression analysis. We assume these two will help to complete the picture of municipal waste management.

4.1 REVIEW OF OPEN QUESTIONS

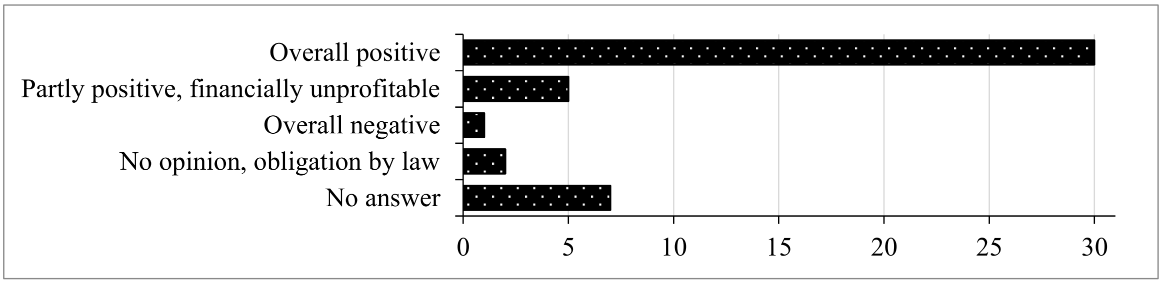
In the questionnaire for the municipalities, the open questions about waste separation were asked. The municipalities had the opportunity to specify the functioning of waste separation under their administration. They were further asked about their perception of municipal waste separation. We believe that these answers provided directly by the municipality representatives help us to better understand the functioning of the system and the motivations of municipalities regarding waste separation. In this particular analysis, the bigger initial sample of the municipalities was included. In the total, we will examine answers by the 45 municipalities in this part of the analysis.

The aim of this analysis is to form a picture about municipal waste separation in the municipalities from our sample so that that more accurate conclusion can be drawn in the end.

4.1.1 Perception of the municipal waste separation

We were especially interested in the perception of waste separation directly by the municipalities. The statistics described at the beginning of this thesis suggested that waste separation is lossy service hence municipalities must endow this activity. The overall perception of it is, however, generally positive in our sample of municipalities, even though some municipalities emphasize problematic financial aspect. The frequency of representation of each perception among our sample is graphically illustrated in Figure 8. In total 30 municipalities in our sample judge waste separation under their administration as overall positive, only one municipality expressed overall negative experience in this regard. Municipalities also take other than financial aspects into account while creating a perception about waste separation, however, only fraction of municipalities in our sample observe financial difficulties regarding waste separation (other municipalities even consider the waste separation as source of financial gain, we elaborate on that in the next subchapter more.

FIGURE 8
OVERALL EVALUATION OF MUNICIPAL WASTE SEPARATION BY THE MUNICIPALITIES



Source: Author, based on data provided by municipalities

Observed benefits of municipal waste separation

The answers to the previous question provided by the municipalities were very variable[66]. Large portion of municipalities (resp. their representatives) representative did not settle for a simple YES/NO answer. They elaborated further by arguing benefits that municipality generates from the waste separation. We decided to grab this opportunity and examine benefits that municipalities recognize themselves. Some municipalities specified multiple benefits; some did not provide any, therefore we only briefly comment on the provided answers.

Municipalities see one benefit from waste separation in environmental protection. This is, however, benefit with wide societal dimension and not specific to the municipality. The municipal specific environmental protection could then be the fact, that waste separation *prevents setting up of black dumps*, as cited by a couple of municipalities in our sample. Municipalities further recognize financial benefits of 2 types: First, the *revenues from the EKO-KOM company*, that help them partially cover costs of MWM. And second, municipality *saves the cost from landfilling* of municipal mixed waste[67]. Another cited benefit was that waste separation *helps to keep public space clean* because collection points are relatively frequent and accessible. Last but not least, the municipal waste separation is according to these answers also advantageous for the *citizens*, because they can also *pay less for their waste* (if waste separation reduces total cost of MWM the charges for citizen can be lower). Another argument in this regard was as follows: when citizens participate in waste separation, they reduce in the same time the volume of their mixed waste; hence they pay less in charges. This is however applicable only in the case that some motivation means take place (i.e. lower fee when separating waste, a fee according to the weight of the mixed waste, a fee according to the frequency of mixed waste collection, etc.). Either way, it seems that municipalities see their own benefit in citizens wellbeing. All above-mentioned benefits are summarized in Table ***12***.

[66] The exact question asked was as follows: *What is your personal opinion about whether or not is the waste separation in your municipality worth it?*

[67] I.e. they pay lower landfill fee

TABLE 12
SUMMARY OF OBSERVED BENEFITS OF WASTE SEPARATION BY MUNICIPALITIES

• Revenues from the EKO-KOM company • Cost savings from landfilling • Preventing black dumps • Helping keep public space clean • Citizens pay less

Source: Author, based on data provided by municipalities
Note: benefits are ranked according to the frequency of presence in the answers provided by municipalities

It is important to note at this point, that any conclusion cannot be drawn from this particular section. All cited benefits are so specific to the specific municipality that any general conclusion would be perforce wrong. This part has just informative value to us.

Observed problems of municipal waste separation

Following the previous question, we asked municipalities representatives what specific problems the municipal waste separation creates. Same limitations as in the previous section apply here; this section also has primarily informative character.

Municipalities again frequently cited also the problems with a range exceeding the context of one municipality, e.g. questionable utilization of separated waste as secondary raw materials and continually growing *amount of generated waste*[68].

The biggest problem[69] in regard to municipal waste separation see the municipal representatives in *citizens' discipline, resp. lack thereof*. Citizens often throw also other materials than required into waste separation containers, which complicates further processing of separated waste. Or they do not press down larger items so that the containers are often overfilled, but the actual weight of waste is low. The lack of citizens' motivation is also mentioned as the source of previously listed problems.

Problems are also seen in *relationships with waste collection companies*, that pressure municipalities (e.g. they refuse to take separated waste when contaminated with other materials, they do not allow for a change of waste separation system in the municipality, etc.). Municipalities further *complain about EKO-KOM company*, its non-transparency and the use of a monopoly position by the company.

The *financial aspect* was cited again, this time to the detriment of waste separation. For some municipalities, the revenues from the waste separation are apparently absent, or at least do not outweigh the overall costs of it. Therefore, we will analyze the financial aspect more closely in the CBA analysis to see which financial aspect prevails in reality.

[68] Municipalities then have to increase their capacities accordingly.
[69] Judging from frequency of this problem in answers, overall 9 times from 27 completed answers.

Other problems were cited sporadically, e.g. relatively *large distance to collection points for the citizens* (discourages participation) or the *messiness and unaesthetic appearance* of collecting points, the summary of the observed problems is again included in the table below (Table 13).

TABLE 13
SUMMARY OF OBSERVED PROBLEMS OF WASTE SEPARATION BY MUNICIPALITIES

• **Citizens' discipline regarding waste separation**
• Relationships with contracting partners
• Negative financial balance
• Messiness and unaesthetic appearance
• Large distance to collection points for the citizens

Source: Author, based on data provided by municipalities
Note: benefits are ranked according to the frequency of presence in the answers provided by municipalities

As we can see, some of the problems that municipalities recognize are in fact in direct contradiction to the benefits others have from it. What some municipalities experience as a negative factor by others can be viewed as positive (compare Table 12 and Table 13), which is quite interesting. This only illustrates, that perception of municipal waste separation is specific to each municipality and the settings of it under each municipality administration. For that reason, the following part (i.e. CBA) aims to analyze the efficiency of the municipal waste separation separately for each municipality.

4.2 CBA

The CBA in the case of this thesis will be slightly simplified. We would like to examine the efficiency separately for each municipality, which means that we will not be aiming for one universal net value of waste separation, that is not our goal. The type of the CBA in the case of our thesis will be adapted to that aim and will take the form of an annual ex-post analysis.

In the same time, we would like to avoid possible complication in the form of occurrence of extreme or unusual values in the data provided to us by municipalities. For that reason, we will include more time periods in our analysis, specifically the years 2011 to 2017. The municipal-specific data will be analyzed for each one of the periods separately, and subsequently, the average value for each municipality will be calculated.

In this thesis, we also aim to examine the efficiency of waste separation for multiple municipalities. Both net value per capita and B/C ratio will be calculated. The net value is a useful indicator, but when we aim to compare multiple municipalities, the informative value of it is not sufficient. Net value tells us nothing about the proportion of cost and benefits in the municipality. For that reason, the main effectiveness criterion will be B/C ratio, rather than NV.

From above-specified reasons we will also not follow the recommended structure of CBA as literally as literature (e.g. Boardman et al. 2006; Hanley and Barbier 2009; Riegg Cellini and Kee 2015) suggests. Some of the steps we skip (i.e. projecting costs and benefits over the life of the program), other steps we merge into one (i.e. identifying and monetizing costs and benefits), we will however maintain the most important parts of CBA. We will also follow the guideline of the

European Commission (2014) so that we estimate separately the financial and economic analysis. We believe that comparison of both provides us the useful insight into municipal waste separation problematics.

4.2.1 Identifying the subject of the analysis

In this thesis, we will not focus on evaluation any policy, project or overall system. Instead, we pursue evaluation of a single service, i.e. municipal waste separation, to be the subject of interest. The units of the analysis are then in our case municipalities. In this thesis, we consider a municipality from an institutional standpoint, within the meaning of the Municipalities Act, especially paragraph 2 of the act which states that *"The municipality is a public law corporation, it has its own property. ... The municipality shall ensure the comprehensive development of its territory and take care of the needs of its citizens; in the performance of its tasks it also protects the public interest."* (*Act on Municipalities*) This principle will be most important when we establish the benefits of the municipalities.

4.2.2 Costs of waste separation

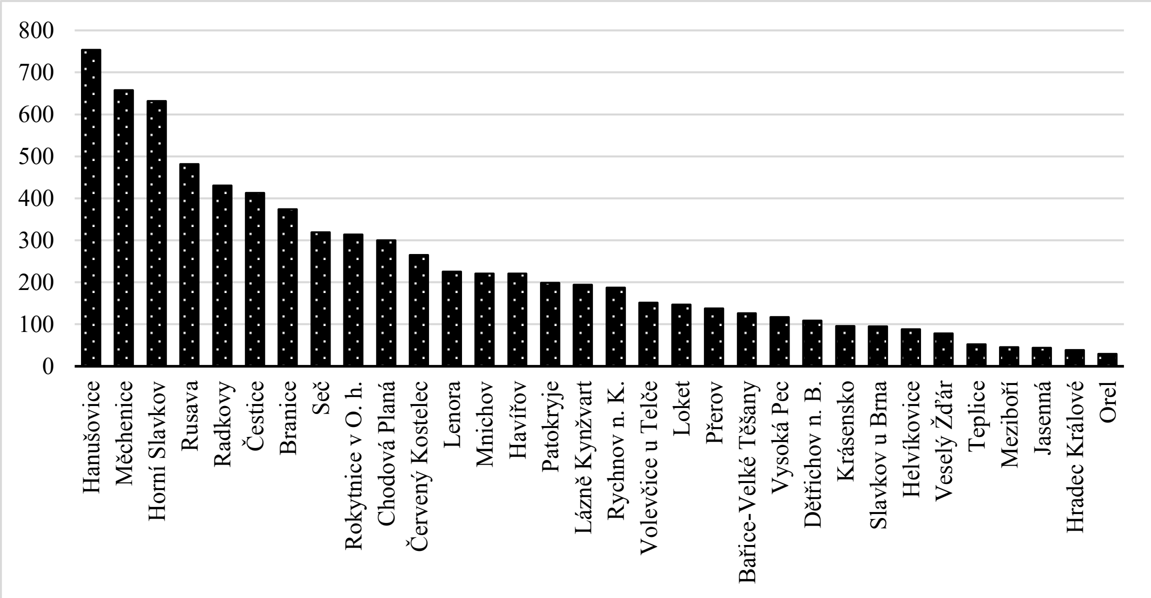
At this point, we need to establish costs and benefits from the waste separation for the municipalities. The cost of a municipality in regards to waste separation is quite straightforward in our estimation: they should approximately correspond with the municipality's expenditure for it. In other words, the municipality has to pay costs linked to the overall management of separated waste (i.e. treatment of collection points, collection process itself, collection trucks or alternatively outsourcing of the service).

Municipalities in the Czech Republic typically do not handle the further treatment of the separated waste, such as recycling and eventually disposal of the unusable residual waste; hence we do not include costs related to this matter in our analysis. In regards of possible negative externalities yield by waste separation, we could definitely find a number of those (e.g. smell or unpleasant view around recycling centers, etc.). Nevertheless, the object of our analysis is a municipality, so we need to consider only externalities tied to the specific communities, not the society as a whole. Since for example recycling centers are not as frequent as individual municipalities, it would be tricky to try to tie the cost from the negative externality to the specific municipality, so we obviate these kinds of negative externalities from our analysis also.

4.2.2.1 Calculation of municipal costs

After establishing the relevant costs for municipalities, we need to calculate the concrete values of costs. As was already mentioned, we aim to examine the efficiency of waste separation for multiple municipalities. Therefore, we will calculate costs in relation to the number of inhabitants (which is the most usual indicator of the size of the municipality). The municipal costs of waste separation per inhabitants, estimated for each municipality in our sample, are illustrated in Figure 9.

FIGURE 9
AVERAGE COSTS OF WASTE SEPARATION PER INHABITANT FOR INDIVIDUAL MUNICIPALITIES



Source: Author, based on data provided by municipalities

As we can see the costs in our analysis vary significantly among municipalities, from the highest costs in the case of Hanušovice worth 753.96 CZK per capita on average to the lowest costs in the case of Orel worth 29.80 CZK per capita on average. The overall average value of costs from all observations then was 229.40 CZK per capita. There does not seem a connection of costs with another determinant of municipalities to occur. The estimation of costs was based on the aggregate information about the expenditure of waste separation provided by municipalities; hence we cannot analyze the cost in great detail at this point.

4.2.3 Benefits from waste separation

Estimation of the benefits in the case of the public sector is obviously more complicated. The waste separation is not a profitable business for a municipality by any means. The only financial earnings that municipality has from waste separation are revenues from EKO-KOM company and the sale of secondary raw materials. However, there must be some other benefit from it. Otherwise no municipality would engage in it, because financial balance is this situation in deficit (see Table 4). We assume that there are some other, indirect benefits linked to municipal waste separation. The only problem is that these benefits are not as easily observable as its costs. In this chapter, we first explore some of the possible indirect (i.e. non-market) benefits and subsequently develop a model which will estimate the monetary value of the waste separation's indirect benefits.

4.2.3.1 Suggested model of indirect municipal benefits

It was already mentioned, that one of the aims of the municipality is to provide services for its citizens and consequently, to provide such services that citizens want or demand. We consider the dynamics of this relationship as the main source of benefits for the municipality: the municipality benefits from the satisfaction of its citizens while this satisfaction is derived from the services the municipality provides. The benefit from this mutual relationship should then include all possible benefits from the waste separation as a sum of benefits of all individual benefits of the citizens that participate in this service. Their benefits should then approximately correspond with their expressed demand for this service.

Now we are getting to a more interesting part: how to estimate the demand for a particular service without observation of the competitive market and knowledge of individual preferences. We will be assuming in this thesis, that the sum of individual benefits of citizens from waste separation corresponds with the overall municipality's benefit from it. Since every household also makes their optimization of costs and benefits, we further assume that households find their equilibrium in regard of waste separation; hence the household costs are equal to household benefits from waste separation (otherwise they would not separate the waste).

Nevertheless, we do not have, available data about individual demand for waste separation. Instead, the aggregate benefit will be estimated[70] using data we know about the municipality. The municipal benefit from the waste separation is calculated using the information about the time that all participants (i.e. households in our case) spend on waste separation and the corresponding costs from spending this time. We can then write the basic equation of the municipality's benefit for our analysis in the following form:

$$B_M = \sum_i^h c_{ti} = T \times P_T, \tag{8}$$

where:

B_M stands for overall non-market benefits for the municipality from the waste separation estimated by the suggested model

c_t stands for individual time costs of households (under the assumption, that benefits for households correspond to their costs)

h stands for the number of households,

T stands for the total time municipality's citizens spend on waste separation

P_t stands for the total price of time (i.e. costs) of the time municipality's citizens on average spent on waste separation.

We can further elaborate on the time, i.e. parameter T in the equation. To calculate this parameter, we use the basic physical relationship of speed, distance and time. Based on this relationship, T can be calculated from a number of trips to collection points by participants, of distance to the collection point and the walking speed. We can write the equation down as:

$$T = \frac{d}{v} p \tag{9}$$

where:

d stands for the average distance to the collection point in the municipality,

v stands a walking speed, which is assumed to be constant and

p stands for the number of trips participants annually make to the collection point

[70] The logic here is that also the municipality has aggregate costs, thus this value is important instead of individual value

For estimating T as an aggregate of the time all participants spend, we need to define a couple of assumptions. Let us break down the above equation by the variables in upcoming subchapters.

The average distance

First, we need to estimate the average distance to collection points. Assume that the distance for every individual participant, i.e. household, to the collection point is the same and hence equals exactly the average distance in a particular municipality. Let us explain this assumption in more detail (the thought process of this is illustrated in Figure 10):

We consider a model municipality that is characterized by its area [S] and a number of collection points [q] as basic parameters (illustrated in picture I). Let us assume, that collection points and also households are distributed around this municipality at regular intervals (picture II) in such manner, that it is possible to divide this municipality into q districts with identical area [S/q], where the average distance for a household to the collection point is identical for each district, and the collection points are situated in precise center of the districts[71]. Ergo the average distance to a collection point in the district should also be equal to the average distance to the collection point in the whole municipality (picture III). In that case, it should be possible to estimate the average distance to the collection point in the municipality by calculating the average distance in the random district of the municipality characterized by its area [S/q] and a number of collection points [1] (picture IV). However, at this point, we cannot estimate the average distance in such district while the district border does have a random shape. Therefore, in order to estimate the average distance, need to theoretically adjust the border shape into a regular circle with collection point in the exact center of it and with the same area (i.e. S/q) as the original district (picture V). This technique (i.e. assuming random shaped area to be a circle for estimation purposes) has been previously used e.g. by Struk (2011).

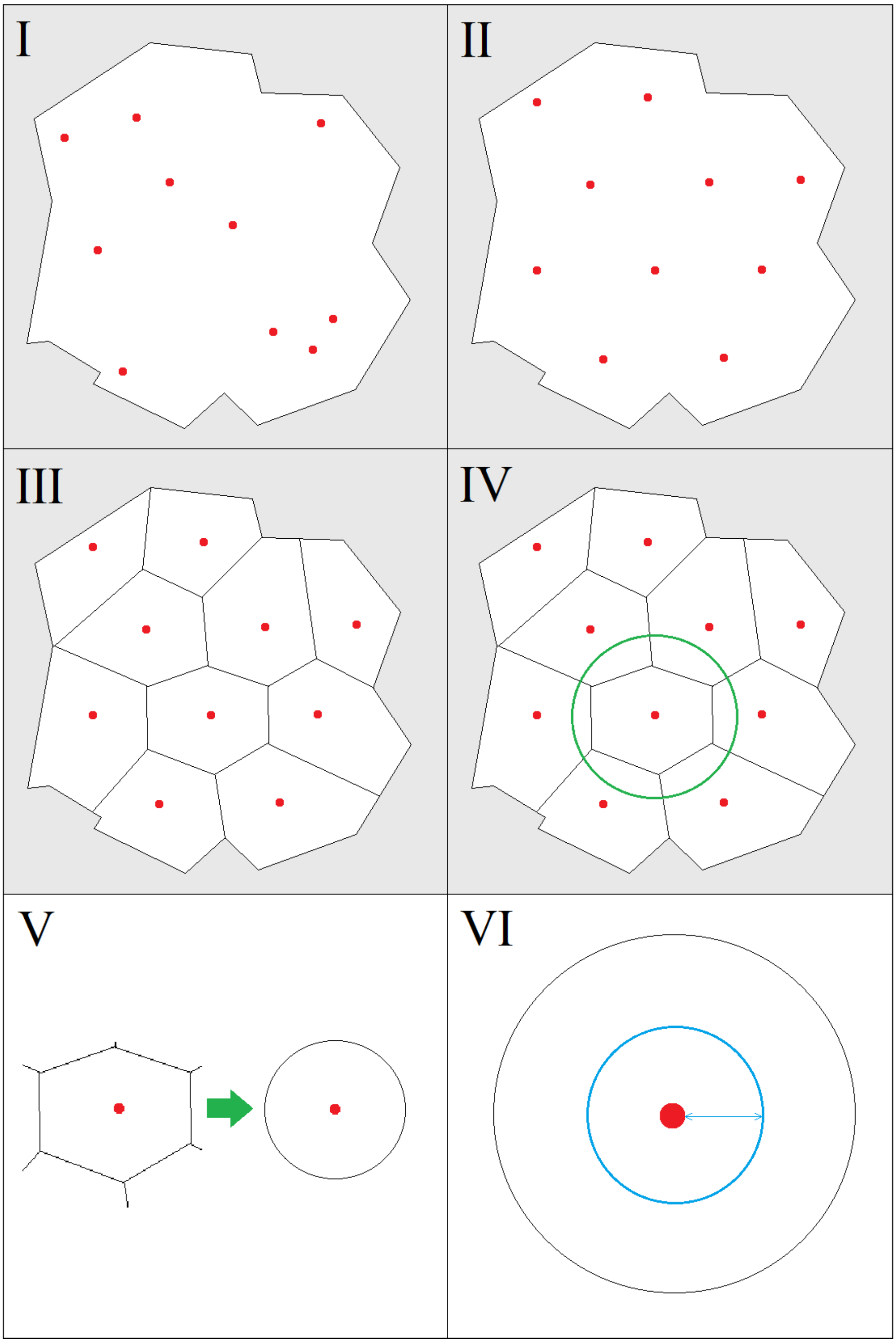
Now we have the circle area with one collection point in its center, with its area equal to S/q and the households regularly distributed in this area. It is possible then to calculate the average distance to the collection point as an average distance of any point of the geometrical disk, which is equal exactly the half of the radius of the disk (picture VI) with the following formula:

$$\frac{r}{2} = \frac{1}{2}\sqrt{\frac{S}{\pi}} \tag{10}$$

Where:
r stands for the radius of the disk,
S stands for a surface of the disk and
π stands for a mathematical constant pi (i.e. Archimedes' constant, ca 3.142)

[71] The multi-story buildings are not included in our model

FIGURE 10
ILLUSTRATION OF ESTIMATION OF THE AVERAGE DISTANCE TO RECYCLING POINT IN THE MUNICIPALITY



Source: Author

When we fit a characteristic of our model municipality into the formula above, we get a new formula for the model average distance to the collection point in the municipality as follows:

$$d_M = \frac{1}{2}\sqrt{\frac{S}{q\pi}} \tag{11}$$

where:
d_M stands for model average distance to the collection point in the municipality
S stands for the area (i.e. the surface) of the municipality and
q stands for the number of collection points in the municipality and

The distance thus calculated is, in fact, a lowest theoretical distance[72]. However, people usually do not fly directly to the collection point; instead they walk on the street. For that reason, we need to adjust this equation (i.e. 10) by adding a constant into it so that this variable will be closer to the reality. The constant was determined to be 1.33[73] so that the resulting distance will be bigger than the model one. The final equation for distance then takes the following form:

$$d = \frac{2}{3}\sqrt{\frac{S}{q\pi}} \tag{12}$$

Walking speed

Also walking speed will be assumed in our equation as a constant. Even though the first half of the trip is made with a burden of waste and second half without it, we argue that the weight of separated waste is not as big to significantly change the pace of gait. The constant walking speed will be designated as constant speed based on available literature for the purposes of this thesis.

It is a usual perception that the average walking speed is around 5 km/h (i.e. ca 1.39 m/s). Naturally, the walking speed depends heavily on other conditions and circumstances, such as age, health, terrain, pace[74] , etc. and hence can vary significantly across the population.

This divergence is also illustrated in the literature. For example, the metanalysis of medical literature on walking speed was made by Bohannon and Williams Andrews (2011). They analyzed over 41 different studies gender- and age-specific data with over 23,000 subjects overall tested. The mean values of gait in studies analyzed indeed ranged between 55.7 and 155.0 m/s for different age and gender groups.

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[72] I.e. airline distance

[73] This value was estimated using relations in the right triangle and trigonometric functions. For the purposes of this estimation we assume, that streets are mostly angled perpendicularly to each other. We assume that the previously calculated model distance corresponds with the hypotenuse of an isosceles right triangle and the maximum actual distance follows both legs of the triangle. We know that both angles, other than the right one, are 45° in this triangle. The sum of leg lengths equals the maximum assumed distance we search for. Hence, the maximum distance is calculated as follows: $d_{max} = 2d\sin 45$. By adjusting this equation, we get the following relationship: $d_{max} = \sqrt{2}d$. Therefore, the constant value we seek for is located somewhere within the interval (1; √2). The final value of the constant was then determined to be 1.33 (we took other factor into account so that this constant reflects the reality as best as possible. i.e. the streets need not be perpendicular, etc.).

[74] According to Bohannon (1997) also height and lower muscle strength are predictors of comfortable walking speed. Knoblauch et al. (1996) in their field study found even more factors influencing the walking speed e.g. vehicle volumes on the streets, the street width, weather conditions, size of groups of pedestrians, traffic lights, curb cuts, crosswalk markings, stop lines, on-street parking etc. This only illustrates, that determining reliable value of this constant will be potentially problematic, without knowing the field.

More interesting for our purposes is a study by Knoblauch et al. (1996), who examined walking speed in the field conditions. They also found that waking speed ranges significantly among pedestrians. They suggest the appropriate average values of walking speed to be 1.22 m/sec for pedestrians aged between 14 and 64 and 0.91 m/sec for pedestrians over 65 years of age.

We will be assuming in this thesis that the external conditions for participants are the same in all examined municipalities, hence do not influence their walking speed significantly. In the same time, we would like to avoid setting this constant too low, because it could influence the result of our analysis in favor of waste separation. We assume that walk with the separated waste is an activity people like to make as fast as possible and not as a pleasant jaunt. Therefore, we further assume the average walking speed for our purposes being rather high, at 1.50 m/s. We further assume, that the trip is always made only for the purpose of separated waste disposal, that they do not utilize this trip to handle any other matters.

Number of trips to the collection points

In order to estimate the number of trips that participants make from their residence to the collection point, we also need to lay down more assumptions. While having in mind the assumption laid down in the previous section, i.e. that there is a constant number of households per the collection point and also the same number of households for all collection points in the municipality.

We will be assuming the constant weight of the separated waste that participants carry per one trip to the collection point. This constant will be designated as m_h in our equation. Since we assume this to be a two-way trip (i.e. both there and back again), we need to multiply the equation by 2. A number of trips to the collection points would in this case be:

$$p = 2\frac{m}{m_h} \tag{13}$$

Where:
p stands for a number of trips participants make to a collection point in a year altogether
m stands for a weight of the separated municipal waste collected in a year
m_h stands for the average weight of separated waste participants carry to the collection point in one trip, we assume this to be constant.

To help to determine the value of the constant m_h an observation of the waste separation behavior of one selected household was made over the span of 4 months. A typical Czech household of "recyclers" with 4 members was chosen to make notes about the weight of their separated waste as they make trips to the collection point. We believe the average weight of separated waste per one trip to be a crucial variable of the suggested model because its value will influence the resulting value of the municipal benefit. For that reason, 3 version of this variable will be considered to make three versions of our model. Based on the household observation (average weht being 1.55 kg), but also on the judgement[75] of the author of this thesis, the average weight of separated waste per one trip was determined to be 1.5 kg, 2 kg and 2.5 kg for purposes of model benefit estimation.

[75] It is useful to acknowledge, that participants do not necessarily decide about their trips to the collection point based only on the weight of the separated waste. They usually base this decision of theirs on the volume of the waste, subsequently based also

Price of the time

The next important variable in this model is the price of the time. We assume the premise from the literature outlined in the preceding chapter: the price of the time is in this thesis assumed to equal the wage after tax. Even though we calculate in this model with the household as a basic unit, in this case, we will make an exception. We will assume, that trip to the collection point is always made by one individual only. Hence the average hourly wage as the variable enters our equation only once. We also omit the possibility of children making the trip because it would be problematic to estimate the value of the free time for them. After all value of this variable will not be household-specific, but rather municipality specific. Which means that we will be calculating in this instance with *average hourly wage after tax*, therefore, we assume that in this case that our estimation for the whole municipality, i.e. in aggregate, will be satisfactory for purposes of our analysis. The equation for the price of the time is in our model as follows:

$$P_t = w \tag{14}$$

Where:
w stands for average hourly wage after tax in the municipality

The only complication is then in the availability of data since municipalities do not gather information about the average wage of its citizens. Neither CZSO does gather municipal-specific data regarding average wages. The most useful data available is, unfortunately, data per *administrative regions* that correspond with NUTS 3 in the Czech Republic.

Data about average wage are also available in the before-tax form. Therefore, we need to adjust these data in order to obtain after tax-wage. The before-tax wage data is further available only in the monthly-form, which means that further adjustment to the hourly wage rate will be needed[76].

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on volume of their household storage containers (they make the trip once containers at home are full). The weight of the separated waste they carry is further influenced by its composition (e.g. plastic materials are lighter then glass etc.).

[76] In the first step the monthly wage after tax will be calculated (see equation 15). This means, that we will need to decrease the monthly wage before tax by the income tax and payments to fund social and health securities. We will not include any tax credits and allowances but one: the basic tax allowance on the taxpayer. The personal income tax for employees in the Czech Republic is calculated as tax base multiplied by the 15% tax-rate (*Income Tax Act* §16). The tax-base for the income tax is then the before-tax wage increased by contributions to funds of social and health securities payed by the employer (*Income Tax Act §6(12)*, i.e. 25 % of before-tax wage to the social fund (*Social Security Act* §7 (1)) and 9 % of before-tax wage to the health fund (*Public Health Insurance Act* §8 (2); Kandlerová 2015), together payments of employer make 34 % of before-tax wage). The employee must apart of income tax make also contributions to the funds of social and health securities himself. The rates for the employee are 6.5 % for the social securities (*Social Security Act* §7 (1)) and 4.5 % for the health securities (*Act on Premium on General Health Insurance* §2; Kandlerová 2015), i.e. in the total 11 %, while base for those is equal to the wage before tax. The only tax discount we take into account in this model is basic tax allowance on the taxpayer which makes in the Czech Republic 2,070 CZK per month (24,840 CZK per year, *Income Tax Act* §35ba).

$$w_M = w_{MBT} - 1.34 w_{MBT} * 0.15 - w_{MBT} * 0.11 + 2070 \tag{15}$$

Where:
w_M stands for average monthly wage after tax and
w_{MBT} stands average monthly wage before tax

/continues on the next page/

Municipal benefit from the waste separation

Finally, we can adjust the original benefit equation (8) by the previously established relationships, particularly the equations of time (9), distance (12), number of trips to the collection point (13) and price of the time (14). The resulting equation takes the following form:

$$B_M = \frac{\frac{2}{3}\sqrt{\frac{S}{q\pi}}}{v} 2 \frac{m}{m_h} w \tag{17}$$

Equation (17) can also be written as:

$$B_M = \frac{4mw}{3vm_h}\sqrt{\frac{S}{q\pi}} \tag{18}$$

The suggested model produces more additional variables. The description of these variables is included in Table 14, while the variables' description statistics can be found in Table 15.

Even though the role of these variables is solely to estimate municipal indirect benefit, we believe that these variables have some information value: they help to describe the municipal waste separation system and citizens behavior in more detail. It is important to keep in mind, though, that these variables are still elicited by model and that the real values might differ if had been available.

TABLE 14
VARIABLES CREATED WITHIN THE MODEL

Variable	Variable type	Units	Description
Model constants			
Speed [v]	constant	km/h	Assumed walking speed in the trip to the collection point
Weight [m_h]	constant	kg	Assumed weight of separated waste citizens carry to the collection point in one trip
Variables calculated within a model			
Trips [p]	quantitative	pcs/year	Number of trips to the collection point made annually in the municipality
Distance [d]	quantitative	km	Average distance to the collection point in the municipality
Time [T]	quantitative	h	Total time spend on waste separation by citizens in the municipality

Source: Author

The second step consist of calculation after-tax hourly wage from the after-tax monthly wage. Unfortunately, the number of working hours is not same every month. Therefore, we need to first calculate the yearly wage, then weekly wage and finally the hourly wage. There is in the total 12 months and 52 weeks in the year, we assume that all employers work full time for 40 hour-week. This assumption is possible as the data from the CZSO are already adjusted to the full-time job. The equation for the hourly after-tax wage is then as follows:

$$w = \frac{\frac{12w_M}{52}}{40} \tag{16}$$

TABLE 15
DESCRIPTIVE STATISTICS OF MODEL VARIABLES

Variable	N	Mean	Standard deviation	Median	Min	Max
Model constants						
Speed [v]	224	5.40	0.00	5.40	5.40	5.40
Weight – model 1 [m_{h1}]	224	1.50	0.00	1.50	1.50	1.50
Weight – model 2 [m_{h2}]	224	2.00	0.00	2.00	2.00	2.00
Weight – model 3 [m_{h3}]	224	2.50	0.00	2.50	2.50	2.50
Variables calculated within the model						
Distance [d]	197	0.46985	0.23498	0.42220	0.10619	1.1766
Trips – model 1 [p_1]	180	418,417.50	964,712.63	56,666.67	1,333.33	5,514,064.00
Trips – model 2 [p_2]	180	313,813.12	723,534.48	42,500.00	1,000.00	4,135,548.00
Trips – model 3 [p_3]	180	251,050.50	578,827.58	34,000.00	800.00	3,308,438.40
Wage after tax [w]	224	106.15	7.35	104.57	94.43	130.86
Time – model 1 [T_1]	180	15,918.63	27,068.83	6,188.54	168.96	144,414.56
Time – model 2 [T_2]	180	11,938.97	20,301.63	4,641.40	126.72	108,310.92
Time – model 3 [T_3]	180	9,551.18	16,241.30	3,713.12	101.38	86,648.73

Source: Author, based on data by municipalities and CZSO
Note: the missing values have been skipped

Values of benefit elicited by suggested model

Once the model was specified, we can proceed to calculations of indirect model benefits of the municipalities resulting from waste separation. The results of all three versions of the model that differ with assumed weight of the separated waste that is carried to the collection points are illustrated in Figure 11 below.

There is a very wide range of model estimated benefits among the municipalities in our sample. The difference between each of the three versions of the model (weight carried to the collection point by a household member at 1.5 kg vs. 2 kg vs. 2.5 kg) is also very well observable. Because this difference among model versions is quite significant (e.g. in the case of Branice the difference between version 1 and three even exceeded 500 CZK per capita), we decided not to continue with all three versions in further analysis. Instead, we choose one best fitting model version of the 3. From now on only version 3 of our model will be considered. The differential of benefit values between the municipality with the highest model benefit (i.e. Branice) and municipality with the lowest model benefit (i.e. Teplice) was lowest when elicited by this version of the model[77]. We also considered the precautionary principle by choosing the version that elicits the lowest values of model benefit. The overvaluing of benefits[78] is frequently cited obligation against CBA; hence we wanted to avoid that. The overall average of model indirect benefits was in this instance 313.34 CZK per capita.

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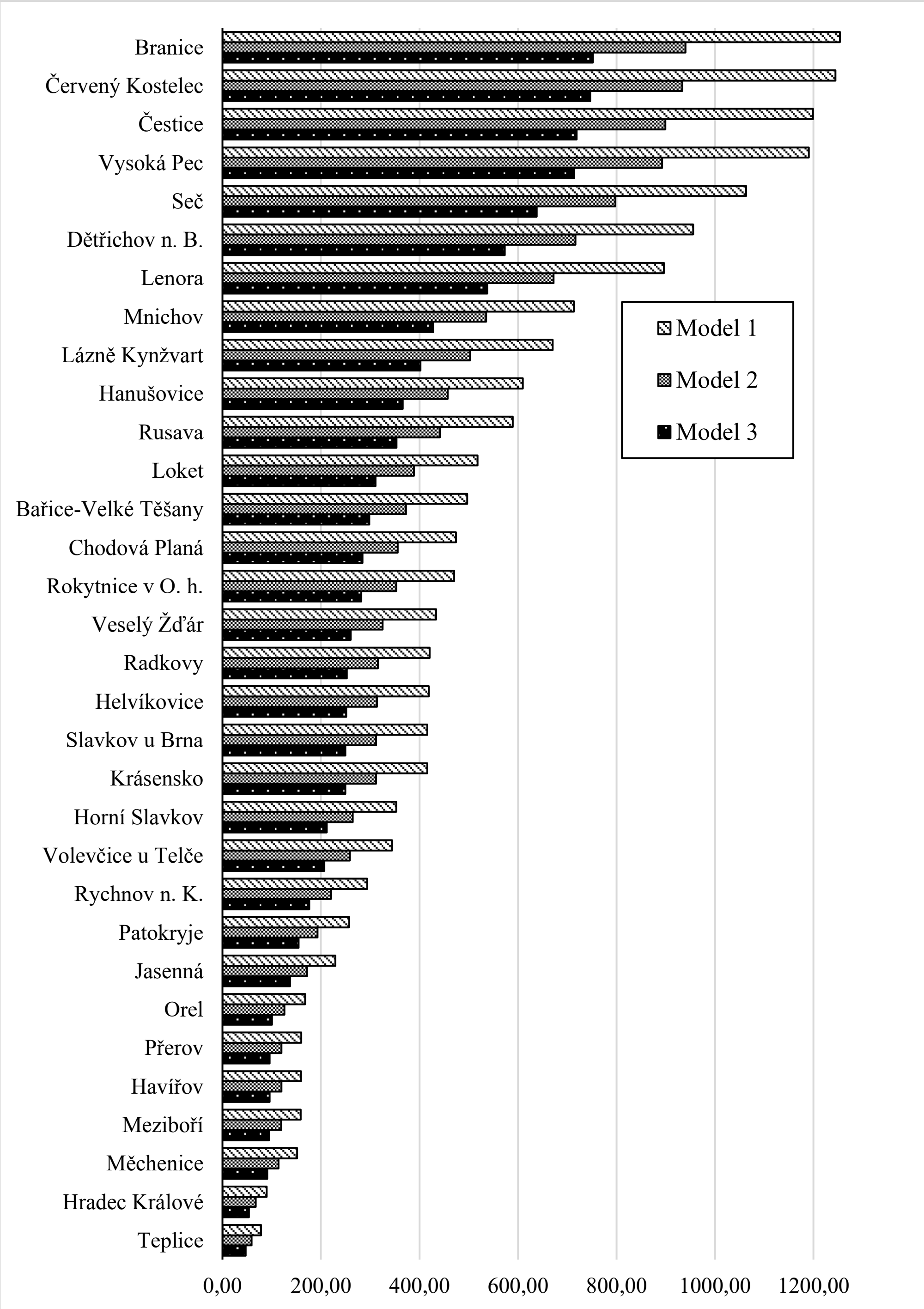
[77] The differential of model estimated values between these two municipalities were 1,174.85 CZK/inhabitant for version 1; 881.14 CZK/inhabitant for version 2 and 704.91 CZK/ inhabitant for version 3.

[78] As well as undervaluing costs.

But now back to actual values of the model benefit. Interestingly enough, the biggest municipalities of our sample (with population 45,000 – 100,000 inhabitants, i.e. Teplice, Hradec Králové, Havířov and Přerov) are all at the end of the spectrum, i.e. they have relatively small model estimated benefit. The reason is behind this could be the relatively short average distance to the collection point that is typical for larger municipalities (between 100 and 200 m according to our model estimation).

FIGURE 11
BENEFITS PER CAPITA ESTIMATED BY BENEFIT MODEL



Source: Author, based on data provided by municipalities, CZSO and own calculations

Calculation of municipal benefit

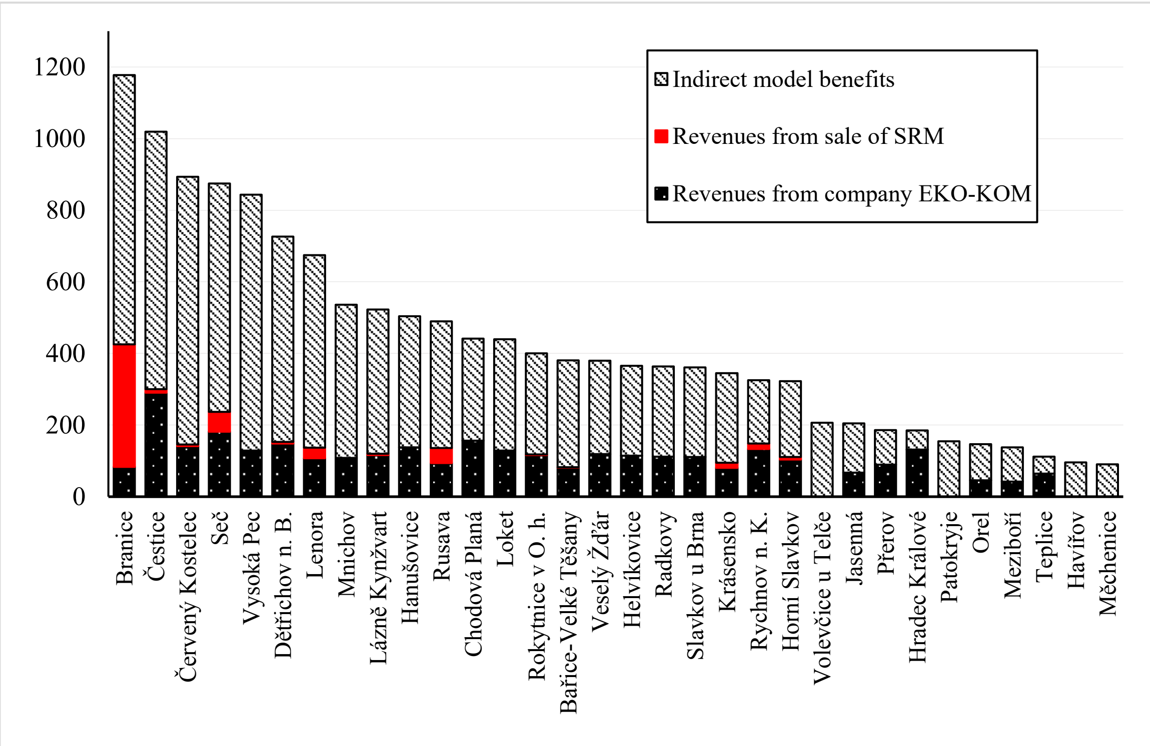
At this point, we know all information needed for the estimation of total municipal benefits. The overall benefit of the municipality consists of 3 components: revenues from the EKO-KOM company, the revenues from the sale of the secondary raw materials and our model benefit:

$$B = B_E + B_S + B_M \tag{19}$$

Where:
B stands for overall municipal benefits from the waste separation,
B_E stands for the municipal benefit (i.e. revenue) from EKO-KOM company,
B_S stands for the municipal benefit (i.e. revenue) from the sale of the raw secondary materials
B_M stands for model indirect municipal benefits

Resultant overall benefit per inhabitant was again calculated separately for each municipality and each year (i.e. 2011 – 2017), subsequently also the average values for each municipality. As already mentioned, we consider only one of three initial versions of model benefit to be relevant in the rest of the analysis. i.e. version 3. Average values of overall municipal benefit for each municipality are illustrated in Figure 12.

FIGURE 12
TOTAL MUNICIPAL BENEFITS PER CAPITA



Source: Author

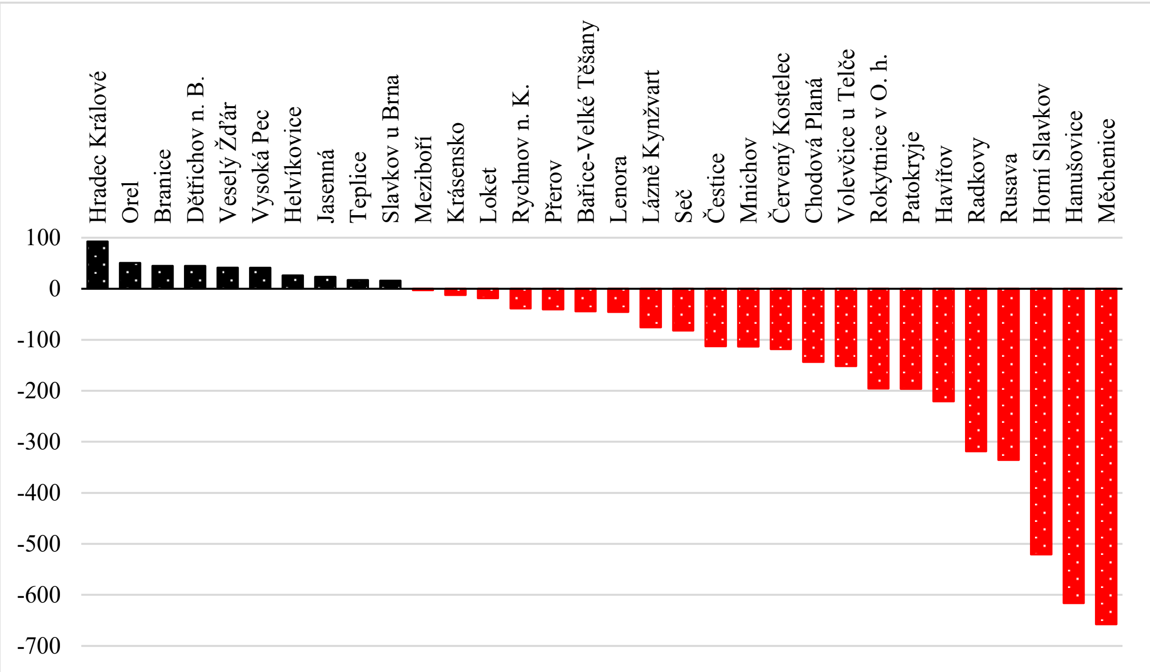
Similarly, as in the case of municipal costs, we can observe the benefit values to range significantly too. In the same time, the model estimated non-market benefits constitute most of the overall municipal benefit. The highest benefits are observed in the case of Branice (total benefit value at 1177.44 CZK per capita on average). This particular municipality also has the highest value of the model estimated benefit (752.09 CZK per capita on average). The lowest overall benefits, on the other hand, are observed in the case of Měchenice (total benefit value at 90.88 CZK per capita), the average value of overall benefit from all observations being 431.49 CZK per capita.

4.2.4 Financial and economic analysis

Finally, we get to the most interesting part: estimation of our efficiency criterion. The key criterion for us will be the B/C ratio; the NV will be however calculated at first, too. We will perform this part in two stages. First, we estimate the financial analysis. The goal of this stage is to see if the perception of financial unprofitability holds. Following this, the economic analysis, that includes the also indirect benefits, will be executed. The economic analysis will help us answer the main question of this thesis about the effectiveness of municipal waste separation.

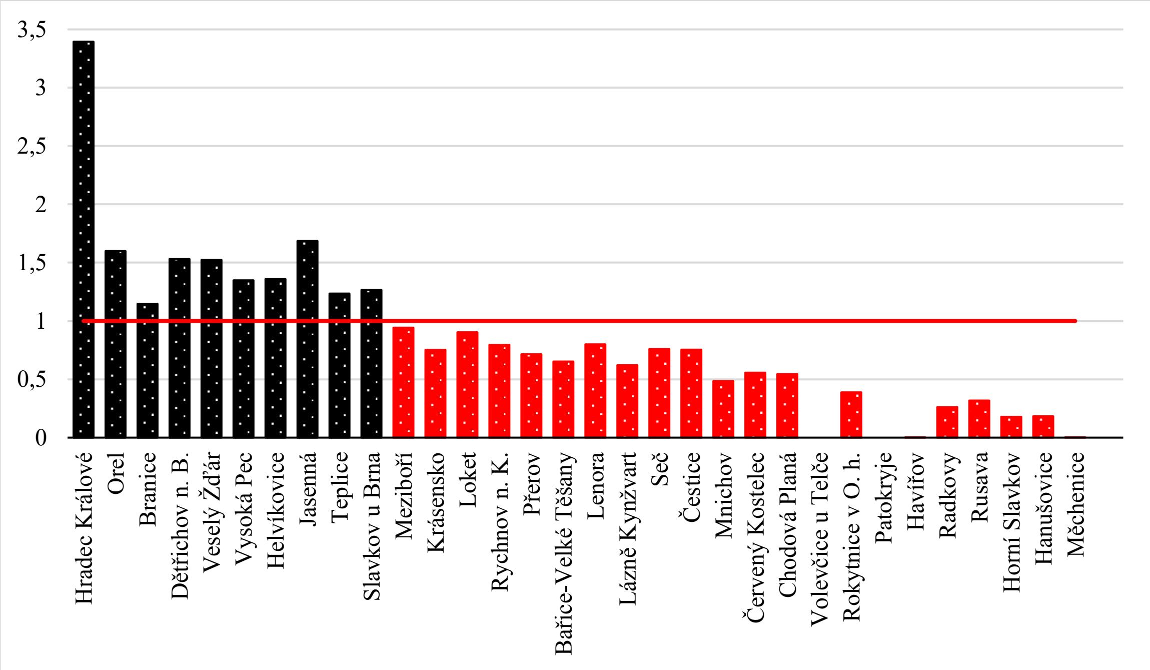
The financial analysis is illustrated in Figure 13 and Figure 14.

FIGURE 13
THE FINANCIAL ANALYSIS – PRESENT VALUE PER CAPITA



Source: Author

FIGURE 14
THE FINANCIAL ANALYSIS – B/C RATIO



Source: Author
Note: the red line represents benchmark value, municipalities are sorted according to financial net value (Figure 13)

The results of the financial analysis show that for two-thirds (22 municipalities out of 32) the municipalities in our sample the expenditure exceed revenues in the case of waste separation under their administration, which means that financial aspect of municipal waste separation indeed creates a deficit to them. Even in the case of the municipalities that gain a surplus, the net value does not exceed 100 CZK per capita. Most successful municipality regarding the financial balance of municipal waste separation was Hradec Králové, with net benefit 93 CZK per capita. In Hradec Králové, on one CZK spent costs corresponds with 3,39 CZK of benefits. On the other hand, the maximum deficit in our sample was even 657 CZK per capita, in the municipality Měchenice. For two municipalities in the sample, the waste separation does not earn any financial benefits at all (i.e. Patokryje and Volevčice u Telče), two other municipalities (i.e. Měchenice and Havířov) report only marginal financial benefits[79]. To sum up the financial analysis, the average value from across observations was -122.33 CZK for net value and 0.82 for B/C ratio. These results confirm the assumption that the municipal waste separation is in aggregate financially inefficient.

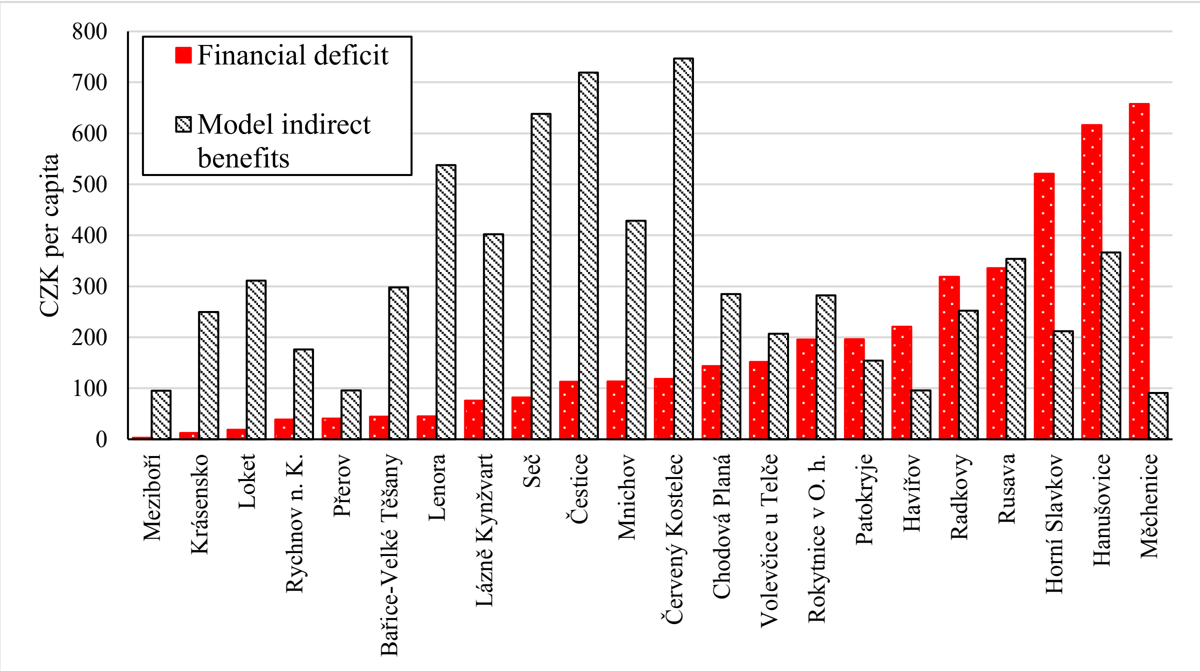
Before we look at the economic analysis of the municipal waste separation, we would like to look closely on the financial deficit of the municipalities in relation to our model benefit. This deficit is the one that must be covered by the municipalities from other resources, typically from the other sources within monetary budget[80]. We would like to especially examine whether the indirect benefits cover for the financial deficit. The premises would then be, that if the indirect benefits

[79] See Figure 14

[80] We assume, based on the available statistics, that the overall MWM is also deficient hence the sources of financing from other revenues of the MWM is not possible.

exceed the financial deficit, the whole waste separation system in the particular municipality is considered as efficient (i.e. total benefits exceed the total costs of this service). For that purpose, we look only at the municipalities that report the deficit[81]. The size of financial deficit and the indirect benefit is illustrated in Figure 15, while their relation in the percentage terms is calculated in Figure 16.

FIGURE 15:
FINANCIAL DEFICIT AND INDIRECT BENEFIT



Source: Author
Note: Municipalities are ordered according to the financial net value, i.e. deficit in this case.

There are only 6 out the 22 municipalities with the financial deficit (and out of the 33 municipalities in the overall sample), whose financial deficit is still not fully covered even after taking the indirect benefits into account. It is reasonable to assume, that the waste separation system of these 6 municipalities (i.e. Patokryje, Havířov, Radkovy, Horní Slavkov, Hanušovice and Měchenice) are somewhat inaccurately set. The result of this is relatively high costs[82] with relative low benefits that imply overall inefficiency of these systems. For the rest of the municipalities, the indirect benefit exceeds the financial deficit, often even multiple times. The most successful municipality is in this regard Meziboří. Even though the indirect benefit is relatively low (95.34 CZK per capita), it exceeds the deficit even more than 30 times (i.e. the deficit is relatively very low on the other hand, only 2.99 CZK per capita).

The percent coverage of financial deficit by the indirect benefits is listed in Table 16. On average, the financial deficit is 603.28% (i.e. six times) covered by indirect benefits. This value seems to be

[81] It does not make any sense to examine whether indirect benefit covers for the surplus.

[82] Compare to Figure 9

rather high. Therefore we include also the median of the percent coverage, which is 307.42 %. Even in this case, the indirect benefits cover the financial deficit more than three times.

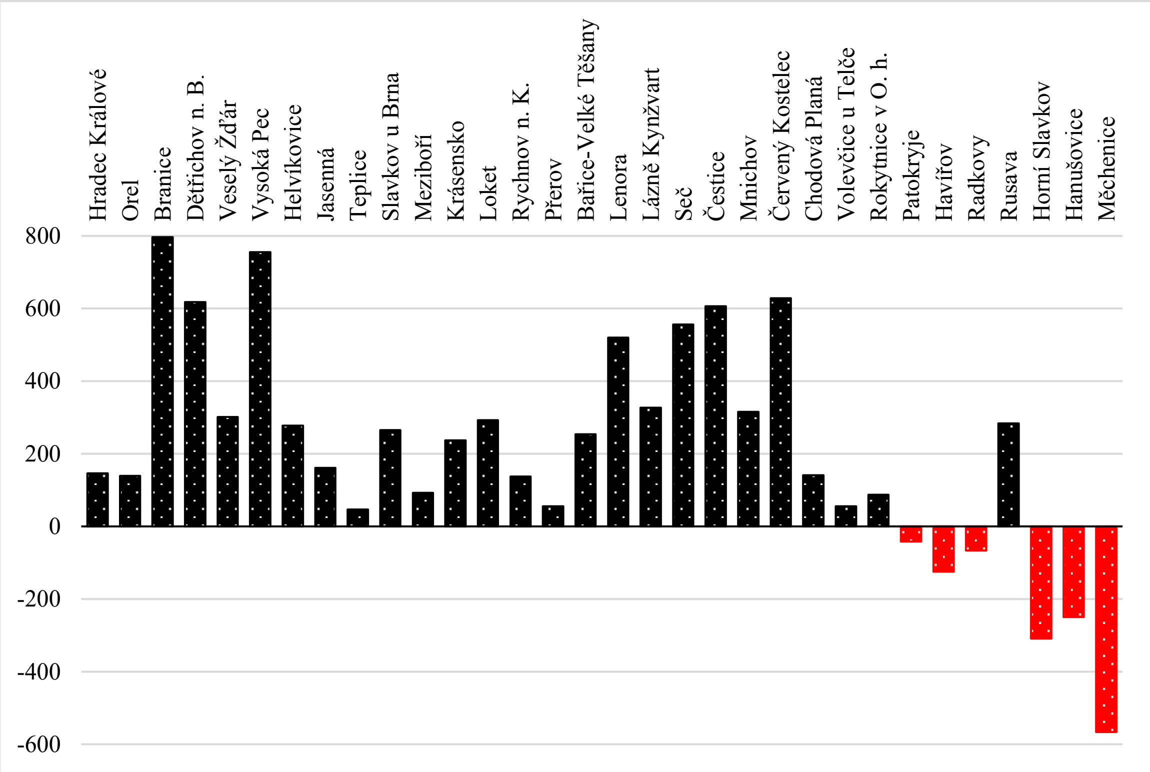
TABLE 16
THE RELATION BETWEEN FINANCIAL DEFICIT AND THE INDIRECT BENEFITS

Municipality	Financial deficit [CZK per capita]	Indirect model benefit [CZK per capita]	The percentage of the deficit coverage by the indirect benefit [%]
Meziboří	2.99	95.34	3,187.57
Krásenko	12.45	249.44	2,003.85
Loket	18.64	310.95	1,668.50
Rychnov nad Kněžnou	38.49	176.29	457.97
Přerov	40.59	95.89	236.26
Bařice-Velké Těšany	44.06	298.04	676.41
Lenora	45.26	537.84	1,187.28
Lázně Kynžvart	75.69	402.27	531.49
Seč	82.17	638.12	776.61
Čestice	112.64	719.32	636.88
Mnichov	113.10	428.19	387.57
Červený Kostelec	118.54	748.87	630.05
Chodová Planá	143.44	284.60	198.41
Volevčice u Telče	151.76	206.82	136.29
Rokytnice v Orlických horách	195.44	282.23	144.42
Patokryje	196.21	154.49	78.74
Havířov	220.65	95.80	43.42
Radkovy	318.77	252.27	79.14
Rusava	335.60	353.58	105.36
Horní Slavkov	520.85	211.86	40.68
Hanušovice	615.93	366.09	59.44
Měchenice	657.37	90.87	13.82

Source: Author
Note: Municipalities are ordered according to the financial net value, i.e. deficit in this case.

In the economic analysis, we assume that the resulting efficiency criteria will separate those 6 municipalities from the rest of the sample as in the previous comparison. The economic analysis was again performed in two stages: first, the net value was calculated (see Figure 16) and then was also calculated the benefit-cost ratio (see Figure 17).

FIGURE 16
THE ECONOMIC ANALYSIS – PRESENT VALUE PER CAPITA

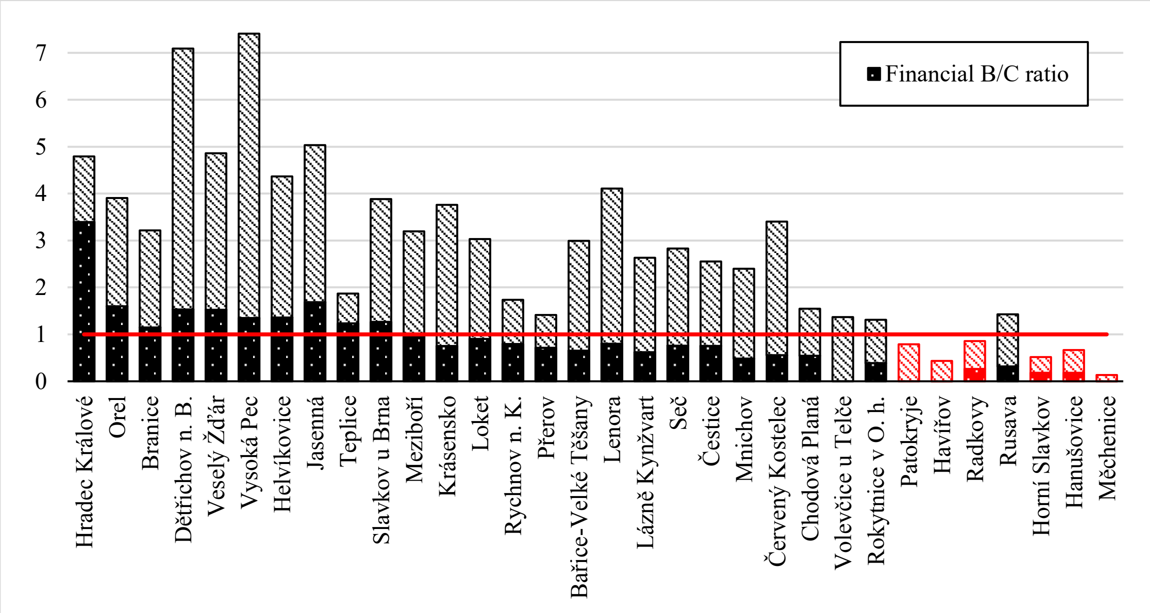


Source: Author
Note: Municipalities are sorted according to financial net value (Figure 13)

Indeed, the results of the economic analysis confirm that for the 6 municipalities in our sample (i.e. less than 20 %) the waste separation is not efficiently provided service. For other 27 municipalities apply that the overall efficiency of the waste separation system is sufficient. The best result of our sample of municipalities is observed in the case of net value for the municipality Branice, whose net value of the municipal waste separation is about 796.87 CZK per capita on average. On the other hand, the worst results are observed at municipality Měchenice, where the net value is about -566.50 CZK per capita on average. The overall average across all observations was in surplus 201.60 CZK per capita.

When we consider the B/C ratio, i.e. how much the total costs are covered by the total benefits, the best results are observed for the municipality Vysoká Pec. In that case, there are 7.41 units of benefit per unit cost. The worst result we again observe in the case of municipality Měchenice, where 0.137 units of benefit per unit cost is observed. And again, the average value across all observation was calculated: it was 2.79, which means that on average the municipal waste separation is considered efficiently provided.

FIGURE 17
THE ECONOMIC ANALYSIS – B/C RATIO



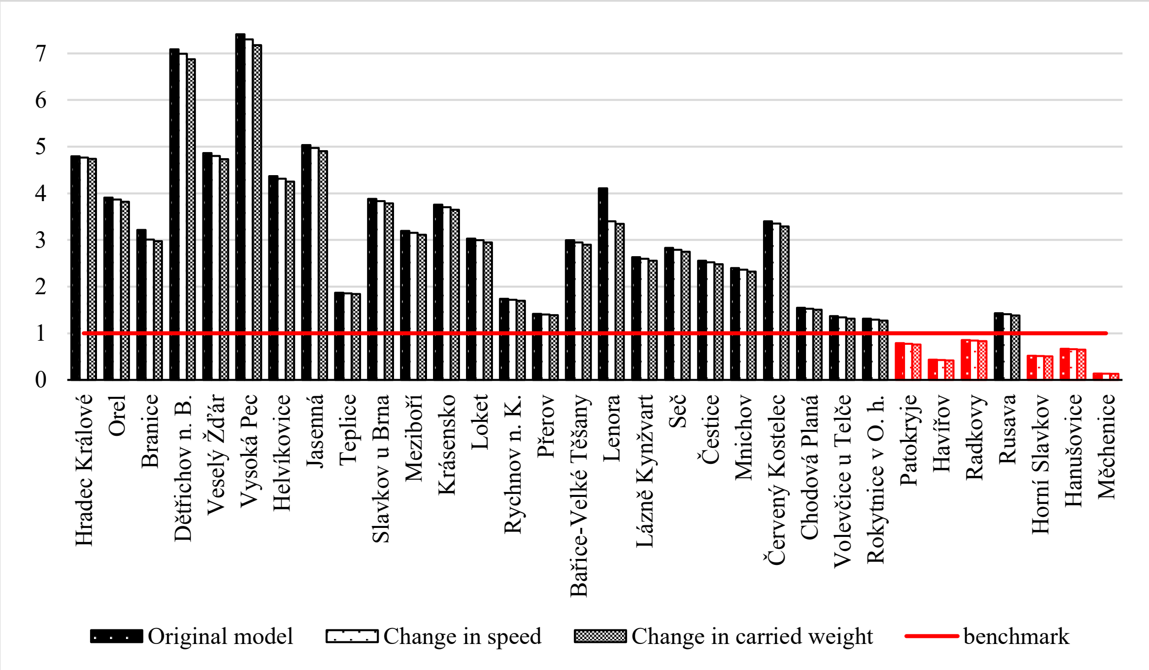
Source: Author
Note: The resultant value of economic B/C ratio is expressed by the total height of the column, the red line represents benchmark value, municipalities are sorted according to financial net value (figure 8)

4.2.5 Sensitivity analysis

The sensitivity analysis is not as important in the case of the ex-post analysis as for the other types. We are calculating with already spend amounts of money. In our model, however, some constants are assumed; hence we would like to test at least for those. We will test our economic analysis in the form of the benefit-cost ratio for changes of the two constants in the model: walking speed and the carried weight of the separated waste. Since both of these constants can be found in the same spot in the model indirect benefit equation[83], the percentage change in the constants would result in the same change for both in the resulting B/C ratio. Therefore, we chose to change both constants by according units: increase the walking speed by 0,1 km/h (i.e. by ca 0,03 m/s) ceteris paribus and increase the carried weight by 0,1 kg ceteris paribus. The increase in both constants was intentionally chosen because the decrease of the resulting benefits is then expected. The percentage change in the resulting criteria will be then observed.

[83] See equation (18)

FIGURE 18
COMPARISON OF INITIAL VALUES OF ECONOMIC B/C RATIO WITH VALUES WITH CHANGED MODEL CONSTANTS



Source: Author

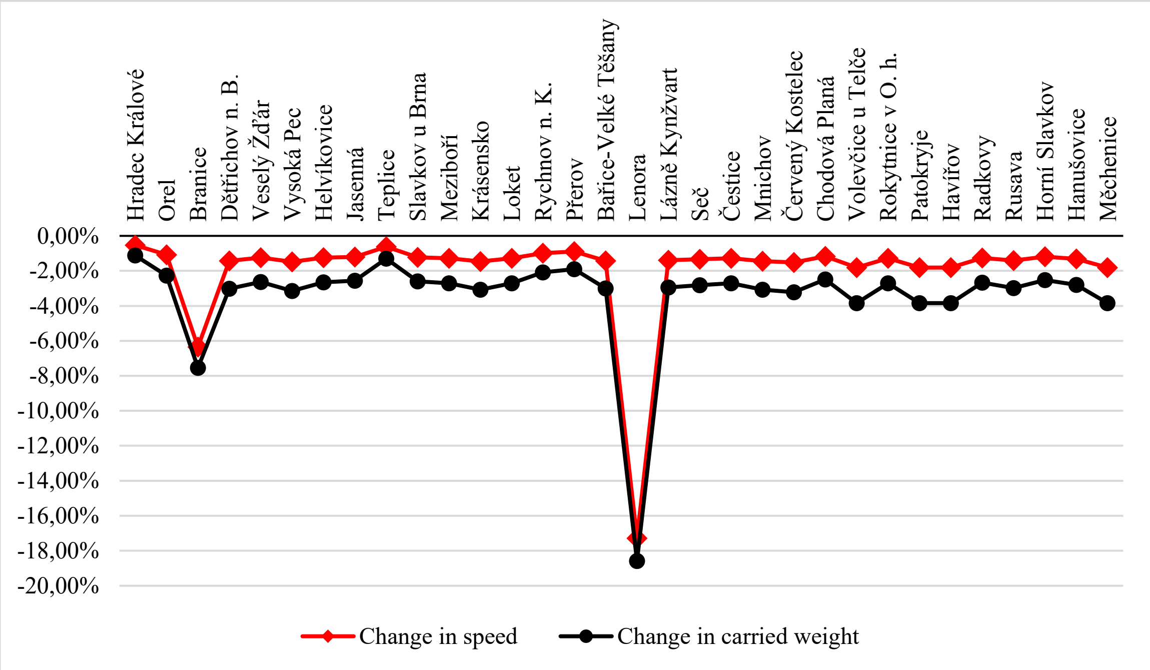
The results of the sensitivity analysis in Figure 18 suggest that for the vast majority of municipalities the change in the model constants does not significantly divert results of the economic analysis from the initial version. The visible difference is observed only at two municipalities in the sample: Branice and Lenora. The most importantly, the overall effectiveness did not change in respect to the benchmarking value, i.e. the waste separation system is still inefficient for the same 6 municipalities as in the initial version.

The percentage change in the resulting economic B/C ratio in the municipalities is illustrated in Figure 19. In the case of a change in the model constant walking speed by increasing it by 0.1 km/h (i.e. 1.85% increase), the change in the B/C ratio can be found within the interval from 0 % to -2 %. Accordingly, the increase in the carried weight by 0.1 kg (i.e. increase by 4 %) results in the decrease of the B/C ratio by value in the interval from -1 % to -4 %. This applies for the most municipalities in the sample with two already mentioned exceptions: municipalities Branice and Lenora. We assume that the fluctuation in the values is caused by the distorted averages calculated in the case of these municipalities. Municipality Lenora reported in the financial deficit in the four periods (years 2012, 2013, 2016, 2017) while there was one period (the year 2011) with the reported financial surplus[84]. The municipality Branice is then quite the opposite case: it reported a

[84] In the 2011, municipality Lenora gained unusually high revenue from the sale of the secondary raw materials compared to other years. For the years 2014-2015 this municipality did not fill values of the costs of municipal waste separation hence the B/C ratio could not be calculated for those two years.

financial surplus in the four periods (years 2013 and 2015-2017) and the financial deficit in one period (the year 2014)[85]. The average values are thus deflected.

FIGURE 19
PERCENTAGE CHANGE IN THE SENSITIVITY ANALYSIS



Source: Author

Other than that, we conclude that our analysis is overall robust to the changes in the values of model constants. The fluctuations in the sensitivity analysis were not caused by the incorrect specification of our model, but rather by big fluctuation in the data reported by the municipalities.

4.3 REGRESSION MODEL OF MUNICIPAL BENEFITS

There is quite lot of literature examining costs of the MWM and recycling schemes (e.g. Lombrano 2009; Bohm et al. 2010; Abrateet al. 2014). The much less attention seems to be paid to the benefits regarding municipal waste separation. Therefore, we would like to look a little bit closer into this problematic, so that the result of our analysis is not only dry statement about the efficiency of the municipal waste separation, but so that we could maybe formulate some recommendations to municipalities officials how to increase the benefit from municipal waste separation.

For the purposes of examination of benefits from the municipal waste separation, we choose to use the regression analysis. The regression model is especially useful when we aim for further examination of relationships between variables, their size and direction. In this thesis we will again use only very basic model and as such will play only a complementary role in our analysis. The

[85] Municipality Branice received lower revenue from the sale of the secondary raw materials in the 2011 then in other years. For the years 2011-2012 this municipality did not fill values of both separated waste production and the costs of municipal waste separation hence the B/C ratio could not be calculated here either.

linear relationships between variables is assumed, hence the method used for the regression in this thesis will be the Ordinary least square method (hereinafter referred to as OLS). The general equation of our regression model will be then as follows (Wooldridge 2010):

$$y_i = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij} + u_i; \qquad i = 1, \ldots, n \tag{19}$$

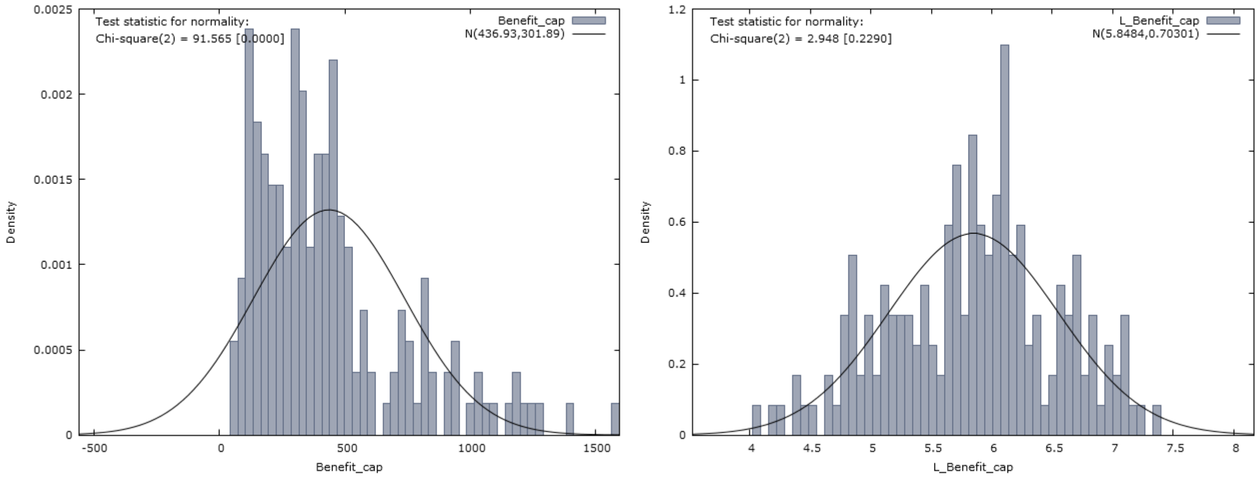
Where:
y stands for an explained variable,
β stands for the regression coefficient,
X stands for a matrix of explanatory variables
u stands for unobserved random variable
i stands for observation number
j stands for the explanatory variable number

The OLS model and its estimates are dependent on several assumptions described by so-called Gauss–Markov theorem (Wooldridge 2010). The assumptions are in brief as follows:

- Linearity (i.e. the explained variable is linearly dependent on explanatory variables)
- Strict exogeneity (i.e. no endogenous explanatory variables)
- Full rank (i.e. full column rank of the sample data matrix; violation = perfect multicollinearity)
- Spherical errors (i.e. the spherical outer product of the error vector violation = heteroskedasticity, autocorrelation)

The explained variable will be in our case the total municipal benefit from the waste separation in the per capita expression (the variable name *Benefit_cap*). The frequency distribution of this variable is however quite skewed compared to the normal distribution (see Figure 20). The logarithmical transformation of this variable could potentially help that. However, the fitted results of in such case will not predict the average value of the explained variable. On the other hand, the advantage of logarithmical transformation is interpretation, that is then expressed directly as percentages. Therefore, we will logarithmically transform this variable for the purposes of the regression.

FIGURE 20
FREQUENCY DISTRIBUTION OF THE EXPLAINED VARIABLE
***BENEFIT_CAP* AND ITS LOGARITHMICAL TRANSFORMATION**



Source: Author using Gretl software
Note: The variable *Benefit_cap* in the left, the variable *L_Benefit_cap* in the right

Regarding the explanatory variables, we aim to include relevant variables based on the real relations with explained variable, at the same time we are restricted by available data. The list of explanatory variables is included in Table 17.

Two models were created for the purposes of this thesis, model (A) and model (B). Models differ by the variable to express involvement in the EKO-KOM system; binary variable was used in the model (A) while the quantitative variable was used in the model (B).

TABLE 17
EXPLANATORY VARIABLES OF REGRESSION MODELS

Variable	Description	Model	Expected relation to the dependent variable
Prod_cap	The production of the separated municipal waste per capita	A, B	+
Coll_points	Number of collection points in the municipality	A, B	?
System	The discrete variable for the waste separation system applied in the municipality; 1 = collection point system, 2 = combination of collection points and kerbside collection	A, B	+
D_EKOKOM	The binary (dummy) variable for participation in EKO-KOM system; 0 = NO, 1 = YES	A	+
R_EKOKOM_cap	The revenue per capita received from the EKO-KOM company	B	+
D_SRM_sale	The binary (dummy) variable for selling secondary raw materials; 0 = NO, 1 = YES	A, B	+
D_IMC	The binary (dummy) variable for participation in intermunicipal cooperation regarding MWM; 0 = NO, 1 = YES	A, B	+
D_Motiv	The binary (dummy) variable for the motivation incentives regarding municipal waste separation; 0 = NO, 1 = YES	A, B	+

Source: Author

We are including only variables resulting from the primary data into the regression model because of the high risk of endogeneity for variables created within the model. The explanatory variable expressing the production of separated waste would be another potential source of endogeneity in the model. The correlation between all explanatory variables was therefore examined to find any other potential sources of endogeneity in the model; the correlation coefficients are listed in Table ***18***. There is not strong evidence for the endogeneity of variable *Prod_cap*, even though the theoretical linkage is definitely there (production of separated municipal waste is most certainly correlated to the factors that produce benefits, i.e. number of collection points, motivation systems, etc.). Nevertheless, because it is expected to be the strongest of the explanatory variables, we decided to include this factor in our model after all.

TABLE 18
CORRELATION COEFFICIENTS OF EXPLANATORY VARIABLES

Prod_cap	Coll_pints	D_EKOKOM	R_EKOKOM_cap	D_SRM_sale	D_IMC	D_Motivation	
1.0000	-0.0548	0.1503	-0.0374	0.3913	-0.0325	0.1090	**Prod_cap**
	1.0000	0.0621	0.9335	-0.1220	-0.1615	0.2225	**Coll_pints**
		1.0000	0.0718	0.1509	0.1256	0.1364	**D_EKOKOM**
			1.0000	-0.1735	-0.1975	0.2891	**R_EKOKOM_cap**
				1.0000	0.5777	0.1420	**D_SRM_sale**
					1.0000	0.2062	**D_IMC**
						1.0000	**D_Motivation**

Source: Author

For all listed variables we assume the positive relation to the explained variable (i.e. with a positive change in an explanatory variable the positive change with explained variable occurs and vice versa with a negative change in an explanatory variable the negative change with explained variable occurs), with the exception of variable *Coll_points*. This variable is in the equation of the model indirect benefit in the present as the denominator[86]; hence the relation should be negative (i.e. with a positive change in an explanatory variable the positive change with explained variable occurs and vice versa). Some of the explanatory variables had, similarly as explained variable, skewed frequency distribution compared to the normal distribution. Therefore, the logarithmical transformation of the variables *Coll_points* and *Prod_cap* took place.

The formula of the regression of model (A) will be in our case as follows:

$$L\_Benefit\_cap_i = \beta_0 + +\beta_1 L\_Prod\_cap_i + \beta_2 L\_Coll\_points_i + \beta_3 System_i + \boldsymbol{\beta_4 D\_EKOKOM_i} + \beta_5 D\_SRM\_sale_i + \beta_6 D\_IMC_i + \beta_7 D\_Motiv_i + u_i \tag{20}$$

The formula of the regression of model (B) will be then as follows:

$$L\_Benefit\_cap_i = \beta_0 + \beta_1 L\_Prod\_cap_i + \beta_2 L\_Coll\_points_i + \beta_3 System_i + \boldsymbol{\beta_4 R\_EKOKOM\_cap_i} + \beta_5 D\_SRM\_sale_i + \beta_6 D\_IMC_i + \beta_7 D\_Motiv_i + u_i \tag{21}$$

[86] See equation (18)

The resulting estimates of both models can be found in the Table 19.

TABLE 19
REGRESSION ESTIMATES OF MODEL (A) AND MODEL (B)

	Model (A) **OLS** ***L_Benefit_cap***	**Model (B)** **OLS** ***L_Benefit_cap***
const	2.270** (0.124)	3.244** (0.147)
L_Prod_cap	1.032** (0.035)	0.678** (0.043)
L_Coll_points	-0.190** (0.028)	-0.180** (0.012)
System	0.010 (0.071)	-0.001 (0.039)
D_EKOKOM	0.185* (0.097)	
R_EKOKOM_cap		0.005** (0.001)
D_SRM_sale	0.025 (0.060)	0.042 (0.048)
D_IMC	0.126 (0.079)	0.166** (0.064)
D_Motiv	0.211** (0.077)	0.105** (0.028)
n	179	176
R^2	0.737	0.873
Adj. R^2	0.727	0.867

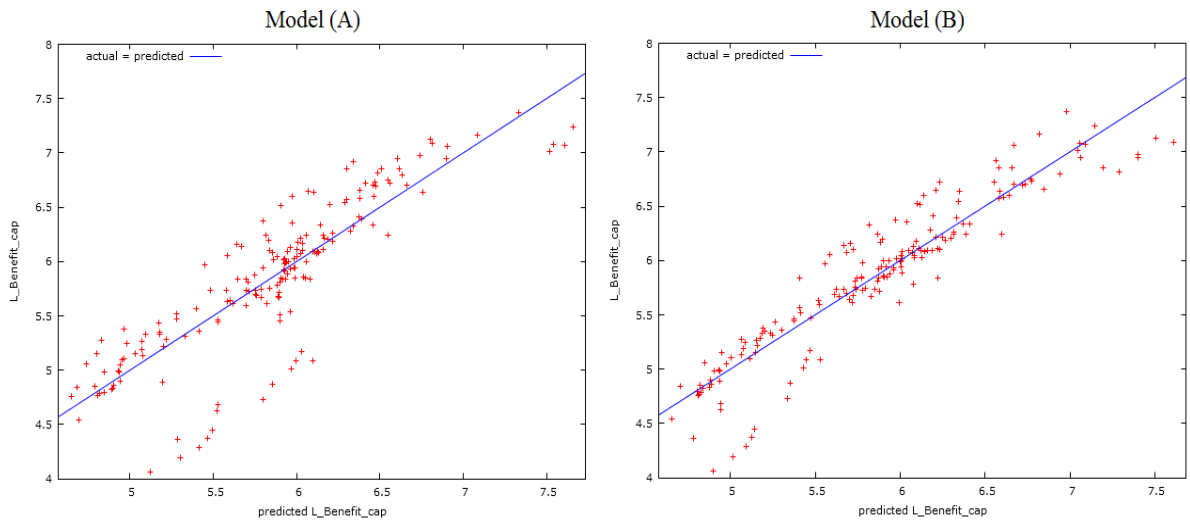
Source: Author
Note: Standard errors in parentheses, * indicates significance at the 10 percent level and ** indicates significance at the 5 percent level

Models were also further tested in regard to assumptions of Gauss–Markov theorem. The exogeneity of explanatory variables was already tested by examination for presence of endogenous variables (using correlation among them). There was high correlation found between variables *Coll_points* and *R_EKOKOM_cap*. This problem is therefore relevant only for the model (B). Another assumption, i.e. that the variance of random component is not final and constant, was tested for both models using the White test. For both models this assumption was violated, there is heteroscedasticity observed in both models. It is not possible, however, to eliminate this problem within models. The OLS method using standard robust errors was at least used, so it is possible to interpret the results. Lastly, the assumption about the full rank of sample data matrix was tested. For this purpose, the variance inflation factor test (hereinafter VIF) was used. The results of this test did not indicate any collinearity problem in any of two models.

The overall assessment of the model significance was tested using general F-test at the level of significance 5 %. The results for the model (A) were $F_A = 516.54$ with p-value(F_A) = $2.93e^{-30}$, while results for model (B) were $F_B = 302.18$ with p-value(F_B) = $1.07e^{-26}$. Because for both test the p-value was close to 0, hence smaller than the chosen level of significance, we dismiss the null hypothesis about the insignificance of models. The model (A) explains about 73 % of variability according to the adjusted coefficient of determination, while model (B) explains about 87 % of the variability. The results of coefficient of determination would imply that model (B) explains relations in this model a little bit better, we have to keep in mind, however, that there is endogeneity problem in the model (B); hence the OLS, in this case, could be biased. For that reason, the model (A) is in our view more reliable. For that reason, we focus our interpretation rather on the model (A).

We illustrate the final result of the regression analysis of both models in the form of the regression line in Figure 21.

FIGURE 21
RESULTING REGRESSION LINE OF MODEL (A) AND MODEL (B)



Source: Author

As for interpretation of regression models, the variable *L_Prod_cap* was not an as strong predictor of the explained variable as initially assumed. The increase of production of separated municipal waste by 1 % results in an increase of municipal benefit from waste separation only by 1.03 % according to model (A). This result has complicated implications, though. The average value of benefit was in our sample was 436.93 CZK per capita which means that the resulting increase would be in units of CZK. Nevertheless, it is not a very good idea to advise municipalities to increase the volume of their waste (any kind, not only separated) in order to increase their benefit, since the decrease of the volume of waste is the ultimate goal. Perhaps to increase the share of separated waste on the total volume of municipal waste would be a better idea.

Neither number of collection points variable *L_Coll_points* does not seem to be the best predictor of the total benefit from the separation of municipal waste from the municipality perspective. When an increasing the number of collection points in the municipality by 1 %, the overall benefit decreases by 0.19 % for the model (A). This paradoxical result is probably caused by the specification of our model of indirect benefits. The variable system showed surprisingly low values, and it was also statistically insignificant in both models. The sale of secondary raw materials was the same case: not statistically significant in both models.

The binary variables *D_EKO-KOM* and *D_Motiv* turned out to be significant in the model as well as having a significant impact on the explained variable. The participation in the EKO-KOM system increases the overall benefit by 18.5 %, the presence of the incentives and motivation means to increase the municipal benefit even by 21.1 %. On the other hand, the variable *D_IMC* had a big impact on the overall benefit (12.6% increase); however this result was not statistically significant. This is logical because only a small fraction of municipalities reported participation in the inter-municipal cooperation. In addition, the inter-municipal cooperation would be probably a better predictor of municipal cost from waste separation then benefits.

5 DISCUSSION

For the purposes of this thesis, the primary data were collected and subsequently analyzed. The potential source of problems is tied to the reliability of these data. The reason is the chosen method of collecting data, that was done electronically. This method when municipality representatives were provided a questionnaire to fill was picked because of its convenience for them. As it was found repeatedly while collecting data for this thesis, the municipality representatives have quite a busy schedule. This is especially true in the case of smaller municipalities, where only a few persons take care about all municipality's administration[87]. With this method, however, space for misunderstanding opens. The municipality representatives were provided a contact for such instances (and it was used a couple of times), but the potential for a mistake can never be eliminated completely. This is the also the reason why quite a big portion of data[88] provided by the municipalities must have been dropped from the sample for the quantitative analyses.

A more significant dimension of this problem was related to the sampling process, i.e. the results of analyzes might be distorted by it: the resultant sample of municipalities is affected by the municipalities' willingness to cooperate. This is when the real problem arises – *the willingness to cooperate was in our case conditional to the perception of municipal waste separation*. The municipalities that view municipal waste separation positively are more likely to respond by filling questionnaire than municipalities that view municipal waste separation negatively[89]. For example: in our sample only one municipality with a negative perception of municipal waste separation by sending back the filled questionnaire. This municipality, nevertheless, could not be included in the sample for quantitative analysis, because data about the costs of municipal waste separation were not filled in the questionnaire.

In this thesis, we came up with a new approach to the evaluation of municipal benefits. We created a completely new model. With every novelty is, however, always associated also high risk. For example, we lay down lot of assumptions. If these assumptions turn out being incorrect the whole model is then corrupted. Nevertheless, the conducted sensitivity analysis suggests, that our model is quite robust. Therefore, we will not abolish our model. The risk of mistake only opens the opportunity for those, who come after us. We would like to encourage and inspire others to examine our model further and eventually polish it to the perfection

[87] Often directly mayor, vice-mayor or single accountant of municipality.

[88] Ca one quarter of data, more specifically data from 12 municipalities out of 45

[89] Just to illustrate this problem, on the more than one instances, instead of filling the questionnaire, the municipality representatives responded to the thesis title by sending one-word e-mail, that stated: "No".

CONCLUSION

The focus of this thesis was solely concentrated on municipalities, namely on the one specific service municipalities provide: the municipal waste separation. The primary goal was in this case examination and evaluation of this service in the case of individual municipalities of the Czech Republic. The additional objective was then to identify the market and non-market benefits (i.e. indirect benefits) for the municipalities associated with the waste separation and eventually to compare these benefits with municipal costs.

In the beginning, the reader is introduced into problematics of MWM, namely then municipal waste separation in the context of the Czech Republic. The aspects and specifics of the municipal waste separation are revealed, including the municipalities' role. The overview of information and data was included to make the complete picture about municipal waste separation.

The theoretical introduction to the evaluation of non-market (or environmental) goods were then outlined in order to lay down the theoretical background for the methods used later for the analyzes. Cost-Benefit Analysis was then picked, since the evaluation and constitution of benefits associated with municipal waste separation were subject of main interest in this thesis. The non-market valuation methods were also discussed with the aim of determining the best fitting methods for the purposes of benefit evaluation of this thesis.

The following sections already belong to the practical part of the thesis, that is built on collected data. The analytical section can be divided into three separately performed analyzes: the analysis of municipalities' perception of municipal waste separation, the evaluation of municipal waste separation efficiency and the identification of sources of municipal benefit from waste separation.

The overall perception of the municipal waste separation, as formulated directly by the municipalities' representatives, is generally positive. The municipalities recognize that the financial aspect is not always profitable, the majority, however, believe, that the benefits from it compensate the financial costs. The municipalities see the most significant benefit in environmental protection, which is in line with the general public perception of municipal waste separation. Therefore, we conclude that it is appropriate to derive some municipal benefits from the preferences of its citizens.

As already mentioned, the quantitative analysis of the was focused more on the benefits of municipal waste separation; hence the CBA was picked as the most fitting analysis method. Because the financial aspect of the municipal waste separation was expected to be in deficit, both financial and economic analysis was performed separately. The financial analysis confirmed the initial assumption: for the majority of municipalities in our sample, the monetary costs exceed the monetary benefits which make the municipal waste separation a deficient service. The average net value was in this case -112 CZK per capita, the municipalities must compensate this deficit from other sources (i.e. from the municipal budget). The overall financial efficiency was examined by benefit-cost ratio, that was on average 0.82 in our sample. This value concludes the financial inefficiency of municipal waste separation since the financial benefits compensate only for 82 % percent of costs.

For the purposes of economic analysis, the indirect (non-monetary) benefits must have been recognized and quantified. The model of municipal benefits from waste separation was suggested as the function of time that municipalities' citizens invest into waste separation. This indirect model benefit was then determined to acquire variable values for individual municipalities (within the interval from 47 to 752 CZK per capita). The average model benefit was then 313 CZK per capita. This means that the indirect benefits from waste separation generally compensates for the financial deficit created by it, often even exceeds it.

The result of the economic analysis, i.e. including indirect monetary benefits into considerations, suggest that for most of the municipalities in the sample the municipal waste separation can be now considered as efficiently provided service. The net value was in this instance 202 CZK per capita on average. The cost-benefit ratio was 2.79 on average, which shows us that the overall benefits (financial and indirect benefits) compensate more than enough for the costs generated by municipal waste management.

In an addition to the CBA, the regression analysis of the municipal benefit from the waste separation was performed, aiming at the identification of benefit determinants. One of the most significant determinants was identified to be the participation in EKO-KOM system. According to our findings, the participation in EKO-KOM system brings about a 19% increase in overall benefit to the municipality. This is not a very surprising finding since the revenue from the EKO-KOM company crates the significant financial income regarding municipal waste separation. The other significant determinants that followed were participation in inter-municipal cooperation (increase by 13 %) and presence of motivation means (increase by 21 %). These findings are in the in accordance with our expectations. On the other hand, the waste separation system introduced in the municipality had only marginal influence on the overall municipal benefit (only about 1% increase in the case of the combination of collection points and curbside collection compares to just collection points). We could, based on our findings, recommend to the municipalities to participate in the EKO-KOM system and also to introduce incentives that motivate citizens to the separation of municipal waste.

The overall evaluation of the waste separation from the municipalities' perspective is now concluded from the introduced findings. We view the municipal waste separation in this context as generally positive. Even though the results of the provision of this service varies significantly among individual municipalities, the general aggregate results remain in favor of waste separation. Therefore, we can at this point answer the question form the title of this thesis as follows: *"Yes, it is worth it."*

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LIST OF ABBREVIATIONS

B/C	Benefit-cost ratio
CA	Conjoint analysis
CBA	Cost-benefit analysis
CEA	Cost-effectiveness analysis
CMA	Cost-minimization analysis
CUA	Cost-utility analysis
CV	Contingent valuation
CZK	Czech koruna (currency)
CZSO	Czech Statistical Office
DEA	Data envelopment analysis
EIA	Environmental impact assessment
EKO-KOM	the Authorized packaging company EKO-KOM a.s.
EU	European Union
HPM	Hedonic price model
IRR	Internal return rate
ITCM	Individual travel cost method
LCA	Life cycle analysis
MCDA	Multi-criteria decision analysis
MoE	Ministry of Environment of the Czech Republic
MoF	Ministry of Finance of the Czech Republic
MSW	Municipal separated waste
MWM	Municipal waste management
NPV	Net present value
NUTS	Nomenclature of Territorial Units for Statistics
NV	Net value
OECD	Organization for Economic Co-operation and Development
PAYT	Pay as you throw
RUM	Random utility model
SSM	Single site model
TCA	Total cost assessment
TCM	Travel cost method
TEV	Total economic value
UN	United Nations
VIF	Variance inflation factor
WM	Waste management
WTA	Willingness to accept
WTP	Willingness to pay
ZTCM	Zonal travel cost method

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APPENDIX

Appendix 1: The questionnaire provided to municipalities

The Waste Separation in Municipalities of the Czech Republic

A data collection form for municipalities for the purposes of the thesis with title:

"Is Waste Separation Worth It? The Municipallity's Perspective."

I. The Municipality Descriptives

I.1 Municipality Name:	
I.2 Identification Number:	
I.3 Region:	

II. What is your *personal opinion* : Is your waste separation service worthwhile in your municipality, or not? Why? How do you evaluate the operation of waste separation in your municipality?

III. Do you see any problem in regarding waste separation? In what? *(e.g. financially unprofitable, etc.)*

IV. What *system of separated collection* is used in your municipality?
(collection in colored containers, kerbside collection directly from homes, etc.)

V. What is (and how it has evolved) the *number of collection points* with colored containers (so-called "nests") in your municipality?

	2011	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Number of collection points [pcs]							

VI. The production of municipal waste:

	2011	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
VI.1 Separated MW [t/year]							
VI.2 Mixed MW [t/year]							

VII. Costs of municipal *separated waste* management:

	2011	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Costs of SepW [CZK/year in total]							

VIII. Revenues generated from separation of municipal waste:

VIII.1 Participate your municipality in the EKO-KOM system? [Yes / No]

VIII.2 The contractual reward from EKO-KOM company:

	2011	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
[CZK/year in total]							

VIII.3 Does your municipality earn some ***revenue from the sale of separated MW*** ? (as secondary raw material)? [Yes / No]

VIII.2 Revenues from the sale of separated MW (i.e. secondary raw materials):

	2011	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
[CZK/year in total]							

IX. Does your municipality *cooperate with other municipalities* regarding waste management?
(especially on the waste separation system) If so, please describe briefly the form (e.g. Municipalities associations, etc.)

X. Motivation of citizens to participate on the municipal waste separation system

X.1 Does your municipality use any incentives for citizens (motivation fees, discounts, etc.)? [Yes / No]

X.2 If so, which ones (describe briefly):

XI. Space for notes, comments and suggestions:

Thank you very much for cooperation and your time!

Best regards
Marie Pojezdná