Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Diploma Thesis

Underground Containers in Prague: Costs and Benefits

BSc. Alice AMBLEROVÁ

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Department of Economics

Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Amblerová Alice

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Thesis title

Underground Containers in Prague: Costs and Benefits

Objectives of thesis

The purpose of this diploma thesis is to evaluate usage of new waste sorting method - the underground containers.The evaluation is carried out with respect to costs and benefits associated with implementation of such a new technique.The evaluation will be carried out within a limited area being part of a capital city Prague, therefore the urban planning issues will be considered.

Methodology

data analysis, selected method for optimisation of spatial distribution, cost-benefit analysis, questionnaire survey

Schedule for processing

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until 1/12/2012 - theoretical part
until 1/2/2013 - practical part - research, questionnaire survey, cost-benefit analysis
until 1/3/2013 - data processing, finalization

The proposed extent of the thesis
min. 70 stran

Keywords
urban waste sorting, recycling, underground container, optimal distribution, cost-benefit analysis

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Recommended information sources

Zákon o odpadech č. 185/2001 Sb. a o změně některých dalších zákonů
List,John,A.: Using Experimental Methods in Environmental and Resource Economics, 2006, Edward Elgar
Callan, S.J.: Environmental Economics, 1996, Irwin

The Diploma Thesis Supervisor
Procházka Petr, Ing., MSc, Ph.D.

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prof. Ing. Miroslav Svatoš, CSc.
Head of the Department

prof. Ing. Jan Hron, DrSc., dr.h.c.
Dean

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Declaration

I declare that I have worked on my diploma thesis titled "Underground Containers in Prague: Costs and Benefits" by myself and I have used only the sources mentioned at the end of the thesis.

In Prague 27 March, 2013

Alice Amblerová

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Podzemní kontejnery v Praze:
náklady a přínosy

Underground Containers in Prague:
Costs and Benefits

Souhrn

Předmětem této diplomové práce je zhodnocení inovativního řešení pro tříděný odpad, které je právě zaváděno na území Prahy 3. Jedná se o tzv. podzemní kontejenry. Tento typ kontejnerů v současné době nahrazuje “standardní” typ. Hlavním důvodem je zvýšení kapacity sběrných míst a dále zlepšení estetiky spojené s tříděním odpadu. Vzhledem k tomu, že podzemní kontejnery jsou náročné na finanční prostředky v porovnání se standardními kontejnery, vyvstává zde otázka nákladovosti. Proto se tato práce zabývá zhodnocením obou typů kontejnerů ve vztahu k jejich interním a externím nákladům a přínosům. Otázkou je, jaká je nejlepší kombinace obou typů kontejnerů při minimalizaci nákladů. Toto je řešeno pomocí zjednodušeného modelu lineárního programování. Vstupní data pro určení výše externích přínosů byla získána analýzou článků a také dotazníkovým šetřením. Avšak nebyla analyzována pouze otázka nákladů. Očekávaným přínosem bylo také zlepšení estetiky. Proto je zahrnuta metoda pozorování již vystavěných sběrných míst. Zrovna tak i názory respondentů jsou sesbírány a analyzovány. V návaznosti na výsledky jsou poskytnuta doporučení pro zlepšení případných nedostatků.

Klíčová slova: podzemní kontejnery, standardní kontejnery, komunální odpad, třídění odpadu, interní náklady a přínosy, environmentální/externí náklady a přínosy, zjednodušený model lineárního programování

Summary

This diploma thesis aims at evaluating the innovative solution being implemented in Prague 3, the underground containers for municipal sorted waste. This type of containers is currently replacing the „standard" containers. The main reason for this was to increase the volume of collection spots and to improve the aesthetics regarding waste sorting. As long as the underground containers are finance-demanding compared to the standard containers, the issue of what are the cost differences comes out. Therefore, this thesis deals with the evaluation of both container types with respect to their internal and environmental costs and benefits. The question is what should be the best combination of these container types in order to minimize the costs. This is solved by a simplified linear programming model. The inputs for the environmental costs and benefits evaluation were data analysis as well as questionnaire survey. However, not only the question of costs was investigated. The improvement should be mainly the increased aesthetics. Therefore also observation of the already implemented sorting spots was carried out as well as respondents' opinion on this new type of container were collected and analyzed. Recommendations based on the findings are included in the final part of the thesis.

Key words: underground containers, standard containers, municipal waste, waste sorting, internal costs and benefits, environmental/external costs and benefits, simplified linear programming model

Introduction

As of the year 1991, the Czech Republic has expressed an active concern about waste management as the first Act on Waste was ratified (Vargová, 2012). Since this time, there is an increasing interest in waste management as long as changes in production, consumption, demography and urban development call for implementation of a functioning, reliable and efficient plan for waste disposal.

The amount of waste produced is increasing in constrast to the limited capacity of our planet to absorb the emissions and waste produced (Decision 1600/2002/EC, pg. 2). The density of population in metropolitan cities is high and therefore there is an overall focus on an efficient infrastructure where the waste system is an important part of it. Under the laws and regulations present on national and supranational level, each country, region and city works on development of a waste management scenario that would ensure the best possible treatment of residuals. Various systems are introduced and innovative solutions are put into practice in order to offer to the city's inhabitants clean and pleasant-to-live-in environment.

However, a change in approach to this issue was revealed, as it is no longer enough to care about the waste produced in a passive way. There is a rising importance of focus on prevention of waste generation as well as material and energy recovery (Directive 2008/98/EC). Along with that, part of the waste management scenario is also provision of waste separation spots in order to allow pre-sorting of waste generated.

In the Czech Republic we are currently facing a situation, when spots for waste separation are present almost in every city and also in every village as long as approximatelly 98 % of inhabitants of the Czech Republic has the access to municipal waste sorting spots (Jak třídit, 2010). The amount of waste separated has increased and became part of every-day life for many citizens, but still there is space for growth in sorting of residuals.

To make the waste sorting more comfortable and also less dirty, to make it comply with increasing demands of preservationist in city centres, in 2006 in Brno, another Czech city, a new type of containers for waste sorting was introduced, the underground containers (Mašek, 2006). The idea spread also to other cities in the Czech Republic, also to its capital city, Prague.

In 2009, one district of Prague has decided to implement this new type of container as a main mean of waste sorting. The goal was to start integrating the underground containers to an existing site of containers for waste separation. This new type of container differs from the commonly utilised ones in several aspects in terms of construction, costs and expected benefits. The promised outcome of these containers was mostly the increased aesthetics in part of the district by moving the trash out of the streets, also to increase the capacity of sorting spots and to prevent vandalism (Sotona, 2009).

Reading through the articles and walking the streets, one could claim the improvement is not obvious, at least the aesthetic one, sometimes the outcome seemes to be rather contradictory to the promise. The diverging opinions on this new type of waste sorting equipment among those who already had the chance to meet it served as a subject matter for this diploma thesis.

1 Objectives and Research Questions

The main objective of this diploma thesis is to evaluate the policy of underground containers implementation within the area of Prague 3 with respect to the optimum combination of the underground and the present type of containers considering related costs and benefits.

From this objective rises the issue of the costs and benefits evaluation. Since not all of the figures to be taken into account are readily expressible in numbers, external costs and benefits also need to be determined. The author shall explain the influence of external costs/benefits on the optimum number of containers proposed.

As long as the inhabitants themselves and their attitudes to waste sorting are crucial for ensuring a sufficient level of waste collected separately, the author also includes the objective to understand what factors related to waste sorting are important and how are they addressed by underground containers.

2 Methodology

2.1 Data Analysis

To set the topic into the conceptual framework, data analysis method is used to analyze related articles, press news, yearbooks, pieces of legislation and other types of documents. As Levine (2006, pg. 1) explains in the beginning of his work, data analysis is about describing facts, detecting patterns, developing explanations and testing hypotheses.

For purpose of this research, data analysis is used mainly to sketch the conceptual background of the issues in question. Also to understand what are the legislative regulations restricting the systems of waste management in the Czech Republic and in the European Union. The outcome of data analysis also provides information about other researches that were carried out within the same subject and their results reached so far. Some findings from the analyzed studies also serve as an input for practical part of this thesis in combination with own inputs.

2.2 Costs and Benefits Determination

To be able to answer the research question and fulfill the objectives, it is necessary to determine costs and benefits related to underground containers as well as standard containers. The method used to reach the result is a modified environmental cost-benefit analysis (ECBA). As described by Perman et al. (2003, pg. 373), the ECBA differs from a standard cost-benefit analysis by including environmental improvements and deteriorations that result from undertaking the project, not only the "internal" benefits and costs - the non-environmental outputs from and inputs to the project.

The reason why the full ECBA is not utilized is that it is not complementary with the aim of this thesis. If the aim was to solely compare two projects with respect to their costs and benefits and to decide, which one of them is to be carried out, the method of cost-benefit analysis would be the most appropriate. However, the aim is to consider related costs and benefits and use them further in a simplified linear programming model. Therefore, the desired outcome of the costs and benefits determination part is to obtain costs per one container (of both types) per year.

To link the findings to linear programming model, all the costs and benefits gathered and computed need to be expressed only in terms of costs. For sake of computation, all benefits recognized with either the underground or standard containers will be thought of as the factor which decreases the costs for the related type of container. In other words, if there are any (internal or environmental) benefits present with any of the two types of containers for waste sorting, these benefits will be subtracted from the costs. This is supported by Pearce et al. (2006, pg. 70) who states that *"all costs can be treated as negative benefits and all benefits as negative costs"*.

The question of which costs and benefits categories will be considered is not discussed in this chapter, but in the practical part of the thesis. The categories are then individually described and included in the computation directly. But in general the author of the thesis strives to identify all categories possible along with what Pearce et al. (2006, pg. 56) state, that any gain or loss that occurred due to the policy implementation, no matter to whom or when it was accured, should be counted in the computation.

To reach the desired outcome, costs per one container per year, several more adjustments and computations need to be made. One of them is consideration of the time horizon. As Lah (2002, pg. 141) states, it is necessary to include time factor within the calculation, as the life cycle analyses better account for the overall effects of policy. To express the costs and benefits in demanding units (per one year and per one container), net present value (NPV) concept is recalled. NPV is explained by Schneiderová as a present value of future costs spent during the project life cycle. According to Perman, the NPV is computed as:

$$NPV = \sum_{t=0}^{t=T} \left(\frac{B_t - C_t}{(1+r)^t} - EC \right).$$

We denote:

B_t internal benefits

C_t internal costs

EC present value of the stream of the net value of the project's environmental impacts over the project's lifetime

r discount rate

t analyzed time period

T life cycle

Within the NPV computation, discount rate has to be determined in order to carry out the computation. However, firstly one needs to be aware that as Perman et al. (2003, pg. 371) state, there is an unwritten agreement among economist and everyone working with NPV, that it is the real discount rate (adjusted for inflation i), not the nominal discount rate d. Hence, the real discount rate r is computed as:

$$r = d - i$$

As long as the discount rate can change the outcome of the computation a lot, especially with long-term projects, it is appropriate to consider a sensitivity analysis after finishing any NPV calculations. As Hanley and Barbier (2009, pg. 7) say, the sensitivity analysis is an essential final stage and it means recalculating NPV when certain values change. In this case, the sensitivity analysis would be carried out mainly because of the changes in real discount rate value. As Lah (2002, pg. 143) presents, it is possible, that a high discount rate might even disqualify one option.

Result of the NPV computation leaves us with the net present value of both types of containers over the whole life cycle of the project. However, as written above, costs per one container per year are necessary for comparison and as long as the life span of each project is not considered the same, equivalent annual costs (EAC) are calculated according to the following formula:

$$\frac{NPV_T}{\sum DF_t} = EAC_t$$

After equivalent annual costs are determined, the costs per container and year are obtained by dividing the EAC by number of containers.

2.3 Willingness to Pay

So far two groups of costs and benefits were mentioned: internal and environmental. Whilst the internal costs can be relatively easily obtained by analysing literature and straightforward computations, to reach for the environmental costs and benefits requires an introduction of another technique, one of the so-called non-market valuation methods: the contingent valuation method (CVM).

To carry out such a method in its full range requires next to experience also quite a significant amount of resources to reach for answers from a significant sample of population. As long as these resources were not available for this research, but still this information is needed to meet the objectives, the author decided to combine results of CVM reached by other authors; and also to carry out a research at least in a small scale. Reason for conducting the research despite the lack of experience and resources is that other authors' resources might not by its concepts or set-up perfectly fit the conditions in area that was chosen for this thesis. The demographic or societal background might differ a lot and that might bias the outcome. Based on this fact, a small-scale research is considered as a relevant support material which's results might be taken into account. Hence a brief introduction of CVM method follows.

Contingent valuation method is according to Corrigan et al. (2007) used to estimate willingness to pay (WTP) or willingness to accept (WTA) for aesthetic value which cannot be determined by differences in market prices. It belongs to a group of stated preference techniques where the researcher sketches a hypothetical situation and asks questions to respondents within this scenario. The main question is focused on revealing the WTP/WTA, in other words people's willingness to pay for improvement in environment quality, or willingness to accept environment quality deterioration.

The process of CVM includes creating a survey instrument (the hypothetical scenario, deciding whether asking about WTA/WTP), using the survey instrument, in this case questionnaire survey. The next step is to analyse the responses, then compute the total WTA/WTP for the population and finally incorporate the results into the ECBA, in this case into the linear programming model (Perman et al. 2003, pg. 421).

Within this research the author decided to ask about the willingness to pay following the recommendation by Broomley (in Brown 1998, pg. 324) who states that where the environmental improvements or gains are considered, the WTP concept is more appropriate. On the contrary the WTA method is more suitable when evaluating losses and damages.

2.4 Questionnaire Survey

Emerging from the previous part, it is now known that a questionnaire survey was created to learn about respondents' WTP for the underground waste sorting containers. However, this was not the only purpose of the questionnaire. Its questions and content will be discussed later on in the thesis, for now the design of the questionnaire is explained.

The questionnaire consists of 11 content-focused questions and 5 socio-demographic questions. The content-focused questions were open-ended as well as close-ended. In one case there was the sequence of chosing one answer from the possibilities offered and the following question enabled asked the respondent to further comment on the previous ansewr he/she gave.

Also two scaling questions were asked using the likert-scaling where respondents were asked to choose one of the five, or one of the four provided possibilities which best match their opinion on the given scale.

Based on the level of measurement[1], within the content-focused questions there are mostly nominal, but also interval questions are included. In the socio-demographic part the same applies, there are nominal and interval questions included.

Most of the questions were single-optioned variables, where only one answer should have been selected. Only one question is multi-optioned, more specifically it was about reasons for sorting/not sorting. Here the author assumed that respondents might have more than one reason and therefore enabling to choose one or more answers was seen as less restrictive.

The questionnaire survey was distributed in paper form as well as via on-line questionnaire survey portal Vyplnto.cz. Altogether 74 respondents were participating. The aimed sample size was (within 75,000 inhabitants and 90 % confidence level) 84 respondents (Raosoft, 2004). 10 respondents were missing to get to the target number, which is a tolerable amount. The return rate of questionnaires was 80 % and the average time needed for completion was 3:19 minutes.

[1] Level of measurement refers to the relationship among the values assigned to the attributes/ answeres for a variable – question/topic (Trochim, 2006).

2.5 Simplified Linear Programming Model

All the data obtained, processed and computed so far, using the methodological approaches and processes mentioned, serve as an input for a simplified linerar programming (LP) model. Its goal is to compute the optimal combination of both container types (underground ones and standard ones) at minimum costs (considering the internal as well as environmental costs and benefits).

An LP problem is defined as a minimization or maximization of a linear objective function which is a subject to linear constraints (Ferguson). In this case, the minization objective function is used as the aim is to minimize the costs. The individual constraints are set up according to limitations resulting from a real world data; these are in general called the main constraints. They may be in a form of equalities or inequalities. The second group of constraints is called nonnegativity constraints which prevent the variables to be negative numbers, which would be in conflict with logic. The variables might than reach zero or higher than zero value.

For the computation of the simplified LP model a simplex method online calculator will be used (Simplex Tableau Method). The objective function as well as the constraint set serves as an input for the tool.

2.6 Observation

As mentioned in the introductory part, there is a visible discrepancy between the goal to improve the aesthetics in the city district, and the actual situation. To be more specific, what disturbes the aesthetics the most is the trash laying around the containers as long as they are often fully used and there is no more space for another residuals to be dropped in. During windy weather, one could see pieces of paper and plastic package flying around and polluting even wider surrounding. The underground containers were supposed to help this and also to prevent from unpleasant smell around the containers especially in warm months of the year.

However, to process this in an objective way, observation method was included into this research to map the surrounding of recently built underground containers.

At the time when the observation was carried out, 19 underground spots consisting of three to four containers were built in the area of Prague 3. All of them were visited three times.

The observation took place during three days in 2012: 23 September, 6 October and 19 October. These days were Sunday, Saturday and Friday, respectively.

The different days were to ensure monitoring the situation on different days in connection with the pick-up days, which were in general (at least as claimed and on most of these spots) Monday and Thursday.

The individual spots were numbered, mapped out and visited. Photographic documentation was taken to monitor the surroundings and the state of the underground containers. The evaluation and data interpretation will be present in further chapters, but for now it can be said, that the level of pollution/cleanliness was observed.

3 Literature Review

To explicitly delimit the scope of this thesis and put it into the context of other issues connected with a broad topic of waste management, a scheme of consequential steps used by Marković et al. (2010) is introduced. They present, that the municipal solid waste management system can be seen as consisting of six categories: 1) waste generation; 2) handling, separation, storage, and processing at the source; 3) collection; 4) transfer and transport; 5) separation, processing and transformation; and 6) disposal.

The topic of this thesis touches mainly the third point – collection of the separated municipal waste. That is to explain why e.g. in the constraints the main focus is on costs and benefits incurred whilst providing sorting containers. The topic of how people process waste handling at the source is also touched within the qualitative analysis of questionnaire survey. On the other hand, the fourth point of transfer and transportation is not considered in terms of spatial distribution of containers in relation with minimization of costs for transportation, but only the costs incurred for transportation based on the number of container spots present are taken into account. The author is aware of possible simplification, but in order to keep the research consistent and reasonably broad, the spatial distribution and related topics will be ommitted.

Also another specification should be done in terms of clarifying the context of this diploma thesis. Even though it has been mentioned throughout the document so far, this thesis focuses solely on the municipal waste, in other words waste produced purely by households and municipalities; the industrial wastes and other categories are not a subject of this thesis.

3.1 Related Pieces of Legislation, Terms and Definitions

On 15 July 1975, one of first documents specifying basic terms regarding waste management issued on the European level was the Council Directive on waste 75/442/EEC. Here it was stated that “the essential objective of all provisions relating to waste disposal must be the protection of human health and the environment”. Basic definitions of waste, disposal and recovery are written in this document.

Later on, based on the Decision No. 1600/2002/EC of the European Parliament and of the Council of 22 July 2002, the EU addopted the Sixth Community Environment Action Programme (6^{th} EAP). It addresses and sets the key environmental objectives and priorities that should be attained. The objectives are also focused sustainable use and management of natural resources and waste (Article 8 of the Decision). It stresses the importance of waste prevention, need for increasing awareness of waste prevention amongst public and also to provide measures ensuring source separation, the collection and recycling of priority waste streams.

In 2008, a Directive 2008/98/EC on waste was accepted as a consequence of previously mentioned regulations and other legal acts. This directive defines basic terms with respect to waste management and also introduces the waste hierarchy to be applied as a priority order in waste policies and legislations. To ensure unambiguity, some of the terms important for this thesis are introduced here:

Waste: any substance or object which the holder discards or intends or is required to discard;

Waste management: the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites;

Collection: the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility;

Separate collection: the collection where a waste stream is kept separately by type and nature so as to facilitate specific treatment;

Preparing for re-use: checking, cleaning or repairing recovery operations, by which products or their components that have become waste are prepared so that they can be reused without any other pre-processing;

Recycling: any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes;

Landfilling: deposit of waste into or onto land and temporary storage of over one year or permanent sites;

Composting: a biological process that submits biodegradable waste to anaerobic, or aerobic decomposition. That results in a product used on land or for the production of growing media.

As was mentioned, the Article 4 introduces the waste hierarchy as follows:

1) prevention;

2) preparing for re-use;

3) recycling;

4) other recovery, e.g. energy recovery; and

5) disposal.

The big amount of documents related to the topic of waste suggest that waste management is certainly an issue that is being paid attention on the highest level and it should not be underestimated nor ommited, rather it is to be included in local plans and policies. Let us have a look how this issue is handled in the Czech Republic.

In the Czech Republic, there are several pieces of legislation covering the topic of waste management. The very first legislative act was ratiffied in 1991, which is much later than e.g. the Council Directive on Waste from year 1975. Subsequently, in year 1995 the first document called Programm Waste Economy was published. In year 1997, the Act on Waste from 1991 was amended and in 1999, document called Conception of Waste Economy was introduced. Today, the waste management is governed by Act No. 185/2001 Collection on Waste, its third version, and it is supplemented by Regulation No. 383/2001 Collection. The last conceptual document which was published on the national level was the Plan for Waste Economy for the Czech Republic in year 2003 (POH ČR, 2003, p. 6).

As well as the European Directive on Waste, the Act on Waste starts with delimitation of important terms and on the top it includes the definition as follows:

Communal waste: all wastes generated by activities of natural persons on the municipality territory, which are classified to Group 20 of the List of Waste, except for wastes produced by legal or natural persons holding a business licence.

The List of Waste is established by the Regulation No. 381/2001 Collection as its first appendix. Waste is sorted into several categories based on during which process and where they originated. Altogether there are 20 groups of waste named. The one relevant for this thesis is group number 20 – Communal wastes. The individual relevant waste groups are plastics: 20 01 39, paper and cardboard 20 01 01, glass 20 01 02.

Naming some of the groups of waste which are collected separately, it is appropriate to mention that there are basically two groups of waste meant for separate collection (Kuraš in Vargová, 2012):

- reusable components – glass, paper, plastics, biowaste, textile, metals;
- hazardous components – residuals of paints, varnish, dissolvents, drugs, fluorescent lamp, batteries, etc.

The main focus of this thesis is on the first group of waste, the reusable waste for which the underground containers are built. The hazardous components of waste are touched only marginally.

Based on the Act on Waste, many responsibilities are being delegated on municipalities and local governments by giving them the right to set-up their own local regulations which further direct waste collection, transportation, separation, usage and disposal, as long as it is in accordance with the Act on Waste (Act on Waste 185/2001 Col., § 17 (2)). Also e.g. the waste hierarchy can be found in the mentioned Act of the Czech Republic, in the § 9a (1) in the very same form as in the Directive 2008/98/EC. Hence the sequence of European and local level regulations and legislation is observed.

Based on the just above mentioned § 17 (2) of Act on Waste, the representatives of the Capital city of Prague have adopted a Regulation No. 5/2007 which made the rules for waste management more specific and relevant for the capital city of the Czech Republic.

In the § 3 it is stated, that the categories of waste to be sorted are paper and cardboard, glass, plastics, voluminous waste and hazardous waste. Also it is set, that city districts may organize separation of other waste components, e.g. the beverage cardboard or biodegradable waste from gardens. In further paragraph no. 5 it is delimited, that physical persons are obliged to separate waste according to categories named in § 3 of this regulation. The frequency of waste collection as well as recommended volume for a residential spot to be provided by the residence owner (flat, house, block of flats) is however determined only for the mixed municipal waste, there are no regulations limiting the frequency of waste collection for the separately collected components of waste.

When presenting the most important and relevant pieces of legislation, we cannot omit the Act No. 477/2001 Collection, on Packaging. This act was ratified together with the act on waste as these two subjects are closely linked together since once package stops being a package, it becomes waste. This act basically sets discretions and duties of business entities for launching packagings into the market; it sets the duty for withdrawing of used packagings and also it determines the amount of waste (in %) that must be recycled or re-used (Zákon o obalech, 2001).

Among others, the Act on Packaging § 16 determines that there exists an Authorized Packaging Entity which is entiteled to ensure collective fulfillment of duty to reuse backward withdrawal of packagings. In the Czech Republic, the contracted authorized entity is corporation called EKO-KOM, a. s. Individual municipalities which provide spots for waste separation to their inhabitants may become part of the EKO-KOM system and thus get remuneration for waste separated. This helps the municipality to lower the costs associated with operation of the waste management system. The EKO-KOM system, as it is now officially called brings together the municipalities, waste collection companies, producers of waste (all physical and legal entities which bring the packaged products into the market), final-sorting line operators and last but not least the processers, who use the separatelly collected and sorted compounds as their resources for production of their own products. These entities might be glass factories, papermills and artificial fibre producers (EKO-KOM, 2011a). That is how the flow of packaging/waste is ensured within the Czech Republic.

However, as this system seems to be unified and valid for majority of municipalities in the Czech Republic, largely fragmented is the responsibility for providing the management system. This is due to the fact that based on the Act on Waste, municipalities are responsible for ruling and providing the communal waste system and in the Czech Republic, there exist more than 6,000 individual municipal systems. As long as each municipality concludes contracts with providers of sorting spots and collectors of waste themselves, it is not possible to keep the costs at a reasonable and efficient level. This fragmentation is seen as one of the main weak point of the Czech waste management system (POH, 2013, p. 271).

3.2 Waste Sorting in the European Union and in the Czech Republic

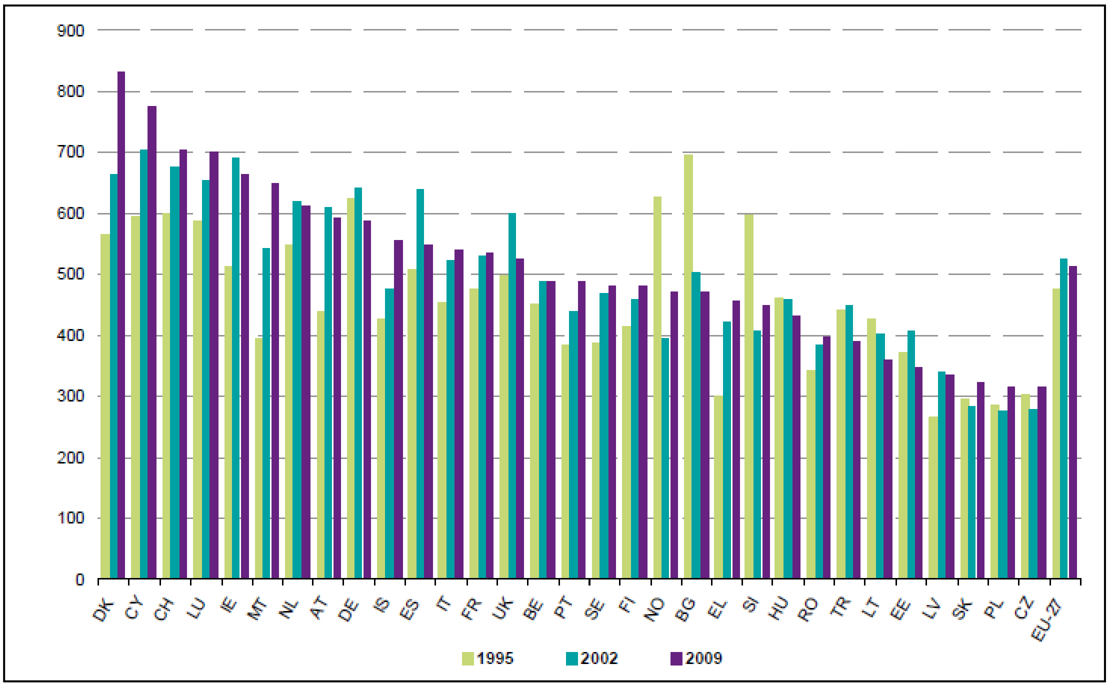
When presenting a comparison of figures, as the following part does, it is important to choose data sources properly in order to maintain consistency. Therefore, data will be provided by the Czech Statistical Office for the local analysis and by Eurostat for the European level analysis.

In Article 11, 2 a) of Directive No. 2008/98/EC, there is a target set for households in terms of how big part they should prepare for re-use and recycling. It is at least 50 % of waste produced. Let analyse how close or far Czech Republic is to this number.

Looking at the statistics provided by Eurostat for EU-27 countries, the generation and treatment of waste differs significantly among individual states, all that changing over period between years 1995 to 2009. Important to mention is the revision of the methodology when gathering data regarding waste across European countries. Therefore data provided since year 2002 onwards are more united and comparable. A brief introduction of firstly the waste generation and secondly of waste treatment follows.

Looking at the Graph 1, which shows the amount of waste generated per country and per capita, we can see that the Czech Republic produces the leaste waste per capita in 2009. The volume is 316 kg opposed to the highest number of 831 kg in Denmark. Such a difference is being explained by differences in wealth of countries, but also in the way how municipal waste is defined, in some countries, also waste from administration and waste produced by sole proprietors is included into this category. The low production is also observed in Poland and Slovakia, other big producers of waste are for example Cyprus, Ireland and Luxembourg. We can observe a significant decrease in waste produced between periods 2002 and 2009 in the United Kindgom and Spain, also some decline was in Estonia and Turkey. On the other hand the amount produced has risen within this period in Malta and in already mentioned Denmark.

Graph 1 Municipal waste generated by country in 1995, 2002 and 2009, sorted by 2009 level (kg per capita)

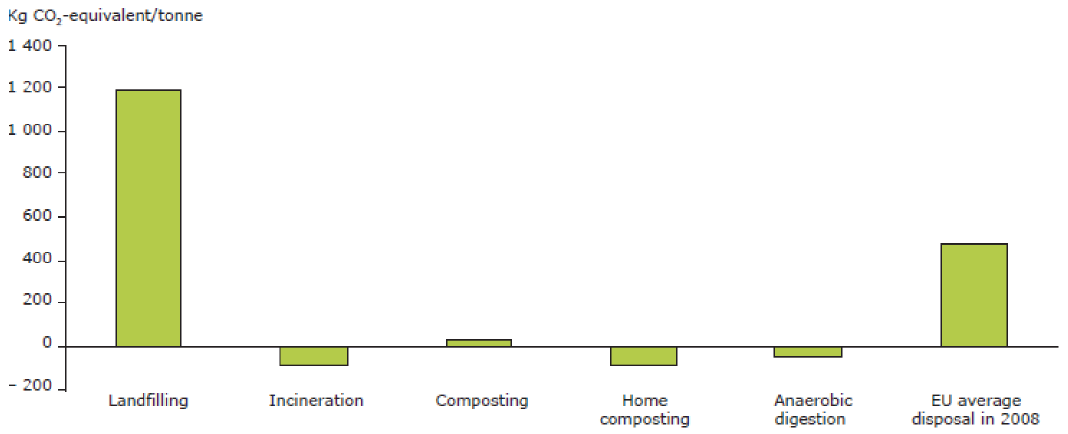


In data provided (Eurostat 2011), four groups of waste treatment methods are monitored: deposit onto or into land - landfill, incineration, recycling and other forms of recycling – includes composting. Before the data anylsis itself, it is appropriate to outline possible differences between the amount of waste produced and amount of waste generated. The difference can be caused by including the import and export of waste, weight losses, double-counting of secondary wastes, which occures when residuals from incineration are further recycled or landfilled. Among other reasons for the disparity is the temporary storage of waste and pre-treatment methods used (Eurostat 2011, p. 3).

Analysing the treatment methods of municipal waste handled in the European Union, the landfill method has noted the highest decrease as the total amount landfilled has fallen from 68 % in 1995 to 38 % in 2008. This is mainly due to the focus of the EU on lowering the percentage of landfilled waste. There were targets set on to which extent this treatment method can be used when handling waste. Also the packaging policy was introduced, by year 2001 all Member States were supposed to recover 50 % of all packagings put in the market (Eurostat 2011, p. 3). In general there was an overall focus to prevent the organic compound of waste from being landfilled; rather other methods should be used, such as composting, incineration and pre-treatment method.

There was a research carried out by European Topic Centre on Sustainable Consumption and Production (ETC/SCP) focused on the link between Green house gas emissions and municipal waste treatment method. Part of the research was computation of net emissions in kilograms and CO_2-equivalent per treatment option of one tonne of kitchen and garden waste. The result is presented on Graph 2. On the first sight it is visible that landfilling is the least environment-friendly method in terms of CO_2 emissions. Unlike the other methods such as incineration, composting and home composting which are much more considerate to the environment (EEA 2011).

Graph 2 Net emissions (kg CO2-equivalent) per treatment option for one tonne of kitchen and garden waste



Note: Emissions cover only the waste management stage of the life cycle.

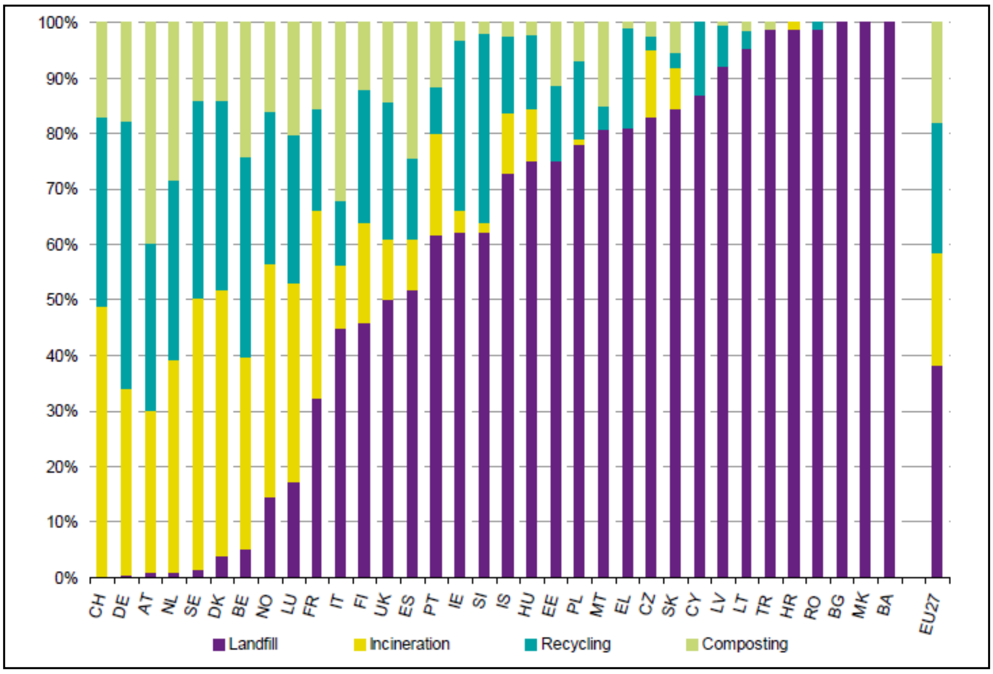
Source: ETC/SCP.

Due to the regulations introduced, the Member States on average experienced between years 1995 and 2009 a big shift from mostly landfilling to increased utilization of recycling, composting and incinerating methods. On average, the EU seems to be going the right direction in waste management. However, it is important to consider how individual countries approach this issue. Looking at Graph 3, we can observe that in many countries, e.g. Croatia, Romania, Turkey, Latvia, Lithuania, and also non-EU countries such as Bosnia and Herzegovina and fYR of Macedonia, the landfilling is still the most used method of waste treatment and contributes by more than 90 % to the division of methods. However, on the left side of the graph we can see countries where the landfill percentage is no higher than 5 %. These countries are Germany, the Netherlands, Sweden, Austria, Denmark and Belgium. The reason why this percentage is so low is the legislative restrictions. E.g. in Sweden and Denmark, there is a law banning the landfill of waste which can be combusted, in the Netherlands there is a ban on direct disposal of mixed municipal waste. In Austria and Germany, landfilling of untreated waste was banned in 2004 and 2005 respectively.

The highest shares of composting are reported by Austria and the Netherlands, where these two countries compost 40 % and 28 % each, respectivelly. The Czech Republic reports the composting rate on 2.2 %, which is a minor contribution.

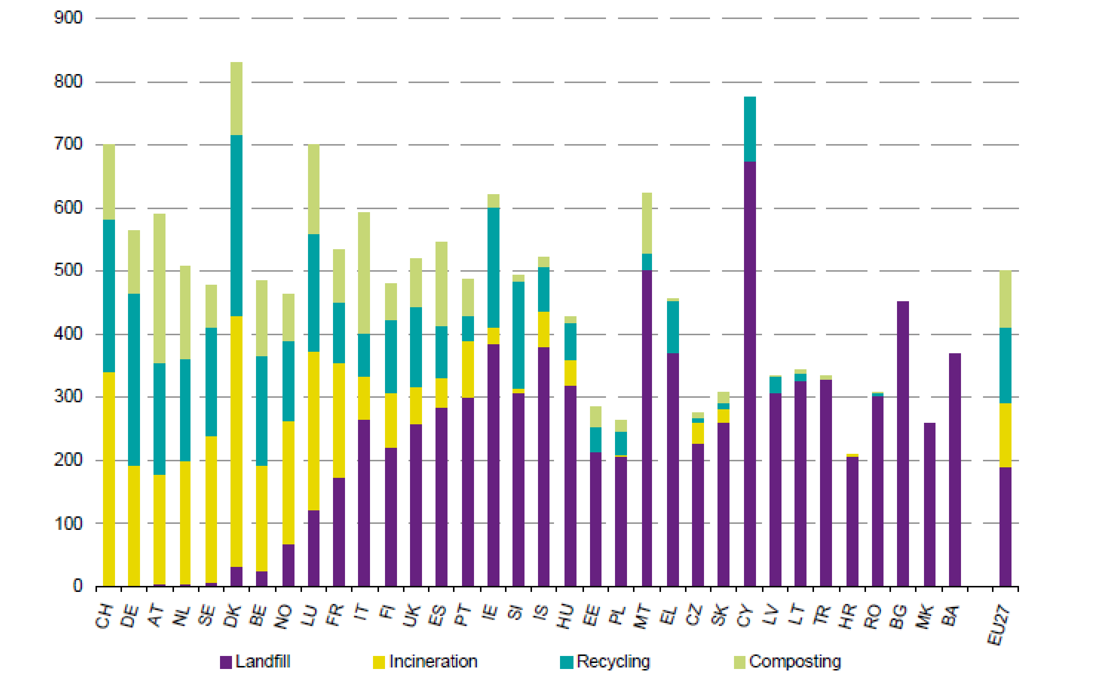
Countries contributing the most by recycling of municipal waste are Germany with 48 %, Sweden and Belgium with 36 %, again in the Czech Republic; the share of recycling method on the total amount of waste treated was 2.6 %.

Graph 3 Municipal waste treated in 2009 by country and treatment category, sorted by percentage of landfilling, (% of municipal waste treated)



A discrepancy can be concluded from the analysis so far when a positive development in waste treatment method was described as a shift from landfilling to other methods; however the graph is more or less covered by violet colour depicting just the landfill method. To make this clear, last illustration Graph 4 is presented which moves us from relative to absolute numbers. We can comment that countries which have a large share of landfill method used are at the same time countries which produce a little waste compare to the other side of the spectrum where we can find countries with no landfilling but high volumes of waste produced.

Graph 4 Municipal waste treated in 2009 by country and treatment category, sorted by percentage of landfilling, (kg per capita)



Source: Eurostat (online data code: env_wasmun)

The previous part so far introduced the situation in the European Union, but as long as this thesis focuses mainly on the Czech Republic and more specifically on its capital city, Prague, presentation of situation with waste management, generation and treatment and its development within last few years follows.

The last period of time for which there exists a complete set of information about waste generation and treatment in the Czech Republic is year 2011. Therefore the analysis will be introduced for this year and the predecessing ones. In year 2011, the total amount of municipal waste produced was 3,357,877 tons. This volume collected consisted mainly of mixed waste - 73 %. The commodities collected separately formed 14 % of the total municipal waste and 11 % was occupied by the bulky waste. The remaining 2 % came from the waste form municipal services. For better understanding, the total amount of municipal waste is a relatively small amount compared to the amount of residuals produced within business where it was 19,918,509 tons. Hence out of the total waste produced, the municipal waste accounts for 14.43 %.

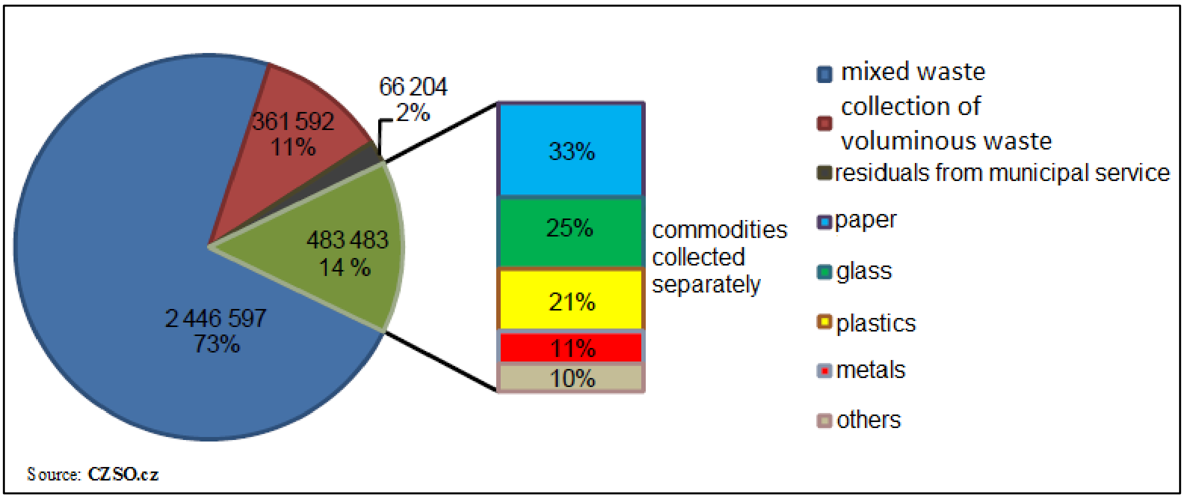
When the total municipal waste produced is divided by the number of inhabitants, we get a number 320 kg, which tells us the average generation of waste per capita per year.

The development of municipal waste capita has an increasing tendency where in year 2002, an average citizen of the Czech Republic produced 279 kg per year. The increasing trend might be alarming and not perceived positively and the EU policy and appeal to focus on waste production has its foundation.

What is more positive is the development of the amount of municipal waste collected separately. Whilst in year 2002 only 6 % of waste was collected separately, in year 2011 it was 14 %. In real numbers this means growth from 16 kg of plastics, glass, paper and metals per capita per year 2002 to 46 kg of these materials per capita in 2011.

Looking more closely on which commodities are collected separately the most in terms of their volume, the Graph 5 clarifies that the most sorted compound is paper – 33 %, glass is on the second place with 25 % and the plastics follows forming 21 % of separated waste. The rest is divided among metals – 11 % and 10 % of the other compounds. In real terms we speak about 159,550 tons of paper collected separately, 120,870 tons of glass and 101,531 tons of plastics. There were 53,183 tons of metals and 48,348 tons of other materials collected as individual commodities. Out of the 46 kg separated per capita per year 2011 it means, that on average each individual separated 15 kg of paper, 11 kg of glass, 10 kg of plastics and 5 kg of metals and other wastes, each.

Graph 5 Composition of Municipal Waste, in tons. 2011



There is one waste category which still does not have its place among most separatedly collected materials, these are residuals which are suitable for composting. The collection of this type of waste is still not broadly supported by local authorities and only a small percentage is separated. Nevertheless, according to the statistics, the biodegradable waste accounts for 49 % of all municipal waste produced, the amount was in 2011 reported as 1,645,704 tons which is a huge number and still it is not being paid attention within the whole Czech Republic. For example in Olomouc, a city in the Czech Republic located in the North Moravia region, each family house can apply for one dustbin for biodegradable waste at no costs, as long as it is paid within the regular fee for communal waste (Bio odpad v Olomouci).

The last topic devoted to production of municipal waste in the Czech Republic is focusing on production within individual regions of the state. The Czech Republic is further divided into 14 regions (for illustration see Picture 5 in the appendix). The one which produces the most municipal waste per capita is Středočeský region with 517 kg, and the least producer of waste is the Plzeňský region with 240 kg per capita. Within one country this is quite a big difference.

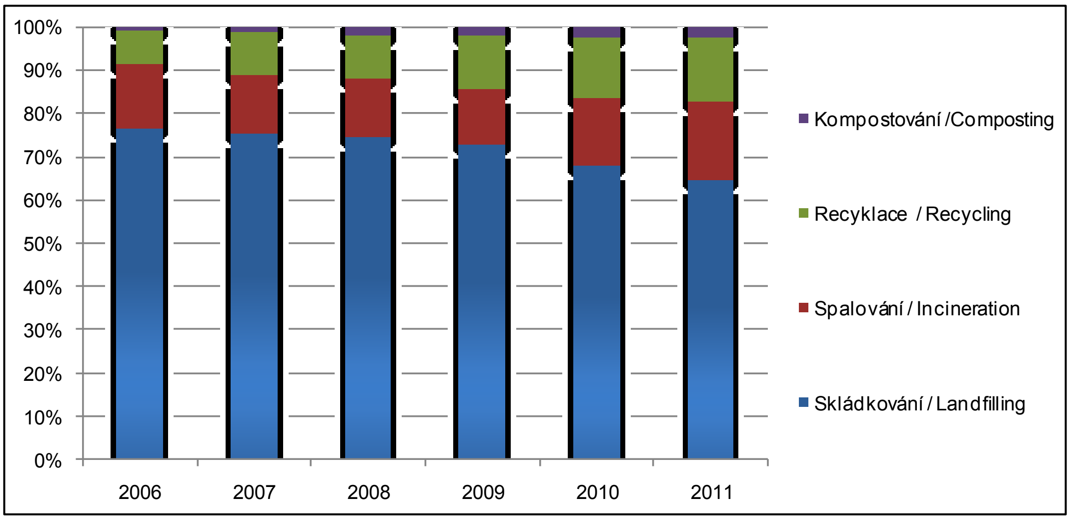
In terms of waste separation, as was mentioned previously, the average amount is 46 kg. Inhabitants of Jihočeský region are those who separate waste the most as they collect 57 kg per capita per year separately. On the other side of the scale are Jihomoravský and Karlovarský region where the average rate is about 36 kg per capita per year. As we can see, there is a 20 % variation compared to the average rate amongst individual regions.

Since this thesis focuses on situation in Prague, one of the 14 regions, data for the capital city are presented separately. The municipal waste produced per year per capita reached 307 kg in year 2011, which is slightly below the average of the whole state. The amount of waste collected separately reached 48 kg per capita per year, which is still above the average 46 kg an together with Liberecký region, Prague is on the 7th place in terms separate collection of waste produced.

Following the similar scenario as when presenting data for the whole Europe, the next few paragraphs introduce the treatment methods and the extent to which they are used in the Czech Republic. In year 2011, together 3,346,338 tons of municipal waste was treated. The difference between the generation and treatment makes 11,539 tons which were not treated according to the Czech Statistical Office (2011). This amount could be stored or exported. However, trade with waste mostly concerns only waste produced by businesses, such as iron metals from construction industry, metals from autowrecks processing etc. In year 2011, 0.4 million tons of waste were imported to the Czech Republic and 2.3 million tons were exported.

For the amount treated, four methods were used: landfill, incineration, recyclation and composting. Historically, always the landfill method predominated over other methods of waste treatment. However, due to the legislation and increasing concern about the environment, the share of landfilled waste is decreasing leaving more space to recyclation, incineration and composting. The development is illustrated by Graph 6. We can observe that in 2006, 78 % of waste was landfilled, about 8 % recycled and only 1 % composted. The share of incineration is slowly increasing from 13 % in 2006 to 18 % in 2011. In the year 2011, the distribution among individual methods is 65 % landfill, 18 % incineration, 15 % recycling and 2 % composting.

Graph 6 Trend in municipal waste treatment



Source: CZSO.cz

The rate of recycling has doubled to 15 %, but still landfill is the most used method of waste treatment. This might cause or already causes shortages of landfill space. Based on the Waste Management Plan (POH, 2013, p. 197), in period 2005 to 2011, 148 dumping sites were operated within the area of the Czech Republic. The average repletion rate was 64 % and the prognosis for upcoming years of availability of space is on average 6 years. In other words, it is predicted that the following 6 years there is enough capacity to landfill waste. However, the situation is not the same all over the country, in Prague the capacity is depleted and has been artificially extended. On the other hand in Pardubický region, the sufficient capacity will be present in following 15 years. The prognosis for Pardubický region is supported by numbers on waste generated in regions, where this region produces the second lowest amount of municipal waste per capita, 273 kg per year (CZSO, 2011).

Moreover, as was indicated above, the biodegradable compound forms 49 % of municipal waste produced, still only 2 % - 73,762 tons were disposed in a corresponding way. There is a big space for improvement, because as long as the waste is not composted, it is being e.g. burnt together with different materials which have higher heating power and thus is incineration inefficient (Arnika, 2012a).

Having presented the situation up to date, next question emerges – what are the targets and trends for the years to come? What are the plans for waste treatment and which direction is the discussion on this topic going? The European Environmental Agency (EEA) has come with two proposals – strategies. Either it recommends focus equally on incineration and material recovery (in both method reach more than 25 % waste treated), or in large on material recovery and a little on incineration (more than 25 % material recovery and less than 25 % for incineration) (Eurostat 2011, p. 7). In general, the first scenario is being adopted by more developed countries within Europe such as Sweden, Germany, France, Austria, Belgium, the Netherlands etc., the second scenario is being adopted by countries such as Finland, Great Britain, Spain and Italy, and other countries fall into the unnamed third category of states with less than 25 % in both proposed treatment methods: material recovery and incineration. For illustration see Picture 6 in appendix.

A controversial proposal was introduced by the Ministr of Industry and Trade Mr. Kuba. He proposed a plan for Commodity policy for the Czech Republic with the aim to focus on incineration. According to his idea, there should be an incineration plant in almost every big city and as of year 2040, 80 % of combustible waste should be incinerated. Unlike one of the two proposed scenarios and recommendations of the EU, Ministr Kuba in his plan ignores material reuse and waste prevention. In order to prevent landfilling, he plans to increase the price of disposal method up to 6x times and push the waste into incineration plants. However, many environmental institutions and public do not fancy this idea. Whether this will be the way for the Czech Republic, we will see (Arnika, 2012a).

With a more environment-friendly and rather opposite solution came in autumn 2012 the politicians from Italy, Emilia-Romagna region. They banned building of new incineration plants and planed a subsequent close of the current plants. They rather focus on recyclation supported by increased publicity. This goes hand in hand with the EU regulations and also it is a more proecological solution (Arnika, 2012b).

The trends in waste management in Europe regarding operational management are according to Němec (2008) attempts for lowering operating costs due to decreasing workforce requirements and increasing the efficiency of technology used. The technological advancement of the trucks enables only one-person service which results in decrease of spendings on wages. In Germany, a system called “HOL” is provided and ensures separation of mainly paper. All the costs as well as benefits are incurred by the provider of the service, thus a free-market competition is supported. According to Němec, obvious are also tendencies to improve the aesthetics and hygiene connected with waste collection in public places. In Germany and the Netherlands, ten thousands of underground container sets are being operated to ensure separation of waste. The development which lies ahead is according to Němec from company SSI Schäfer usage of underground spots for mixed municipal waste.

In the Czech Republic, the waste management is a more or less stable system which does not change significantly in terms of technology or operation. Possible changes are rather local or minor technological improvements of pick-up trucks or collection containers (Kotoulová, 2008). The system of municipal waste collection of recyclables is organized as a commodity collection where each type of waste is collected separately. Inhabitants of cities and other municipal units are supposed to bring their separated recyclables to sorting spots which are spread around the build-up area. On these spots one can usually find containers. However there is also another means of collection – in some municipalities, waste is collected into bags. Those are then not brought, but rather collected at the door-step. The third method used within the Czech Republic is a combination where collection containers are located directly in the house, block of flats or in area with high concentration of houses. The citizens then do not need to go far, maybe only few meters, or they do not even need to leave their home to have the waste collected (Kotoulová, 2008).

Possible shortcomings and advantages of these methods are intuitive. With the bring-in method the citizens need to be motivated and disciplined to participate because the collection spot can be 200 meters away from their home and sometimes not on their way to e.g. work, so it demands extra focus on waste sorting. Both the later mentioned methods are less demanding in terms of how far one needs to go, so these methods are more efficient, however more costly as long as each house or block of flats needs to be collected separately. This leaves us with about 4 people per one stop of the collection truck. Unlike the bring-in spot where there are between 200 to 300 hundreds inhabitants allocated to one collection spot. However, the most spread method across the Czech Republic is just the last one mentioned, the bring-in method of recyclables collection. According to Mrs. Kotoulová, along with the increasing requirements on amount of waste collected separately, the shift from bring-in method to the door-to-door collection method is inevitable.

Part of the system is also created by so called collection yard – big facilities where citizens can drop-off voluminous waste which does not fit into the containers at collection spots, or hazardous waste. These yards have their opening hours within which they operate. Also everyone who wants to drop-off the voluminous or hazardous waste there needs to arrange the transportation on his/her own, which might be sometimes very demanding.

This chapter provided a brief overview on the situation in the European Union and in the Czech Republic in terms of waste generation and treatment; also some trends in this field were introduced. Further and more in-depth analysis of the situation in Prague is presented in further chapters within the empirical part of this thesis.

4 Empirical Part

4.1 Environmental Strategy of Prague

The practical part of this thesis focuses only on waste management system in Prague, and more specifically Prague 3 – one of Prague's districts. Therefore this part is devoted to demographic and geographic analysis of Prague and also to the introduction of how specifically is the waste managed in this part of Prague.

The environmental issues, among them also the waste management of a city, and their strategy and targets for capital city Prague are administered and described in a Strategic plan for Prague. This document was last updated in December 2008 and it focuses on issues such as competitive advantage, inhabitants of Prague, the environment, infrastructure, safety and Prague's development. There is SWOT analysis conducted as a starting point for planning of strategic goals (Strategický plán Praha 2008).

Considering the environment, among strengths there is no point mentioned regarding the waste management. On the other hand, within weaknesses, the last point is formulated as "*a frequent manifestation of vandalism, unsufficient cleanliness on many public places, and here and there inadequate real estate property maintenance*" (Strategický plán Praha, 2008, p. 21). The topic of vandalism and cleanliness is often being connected with the new type of containers – the underground ones, as these should be constructed in a way which prevents from vandalism and pollution of surroundings.

In the opportunities part of the Prague's SWOT analysis, one point of focused directly on waste management: *"efficient and ecologically considerate waste management system (e.g. higher rate of waste separation and its re-use of packagings, etc.)"* (Strategický plán Praha 2008, p. 21).

One of the threats presented is the *"indisciplined managing of materials and waste, risk of soil and underground-wasters contamination"* (Strategický plán Praha 2008, p. 21). Obviously, the issue of waste management is a current topic in Prague and based on the analysis, specific strategic goals were set. In the part of the Plan devoted to the environment, there are two groups covering the waste management. One is P2 Sustainability of material and energetic flows and more specifically P2.1 Minimization of waste produced and maximization of their usage. This goal is further specified by setting sub-goals such as prevention of waste, create conditions for intensification of waste separation with aim to approach 50 % level of municipal waste material recycling in 2010 (paper, plastics, glass, biowaste and cardboard packaging of beverages) and also to spread the network of mobile as well as stable places for waste separation. Resulting from this plan, some changes in the waste management system should be done in order to intensify the collection of sorted waste. Further in the thesis, the introduction of new type of containers is linked to this issue. Often also the idea of unification and centralization of the system is presented. Nowadays, waste collection is carried out by four different companies; each of them operates in certain districts of Prague. Namely these are Pražské služby, a. s.; IPODEC – Čisté město, a. s.; AVE CZ odpadové hospodářství, s.r.o. and KOMWAG, podnik čistoty a údržba města, a.s. (Pražské služby, a.s.). Also as was mentioned above, governing bodies of each district are resopnsible for operating the waste management system, hence the centralisation is not fulfilled in Prague.

A second group from the Plan's part focused on environment is linked to this thesis, it is P3 Sustainable correspondence of urban and nature environment and especially P3.5 Elimination of "visual" pollution. Here it reintroduces the issue of vandalism, which should be efficiently sanctioned. Also it places emphasis on better cleaning of the public places together with handling of municipal waste. The visual intrusion is a generally recognisable issue which needs to be addressed.

4.2 Prague 3 – Demography and Geography

Prague 3 is situated near to the historical city centre of Prague (mainly districts Prague 1 and 2), for illustration see Picture 7 in appendix. You can see that Prague 3 lies with its whole area inside the protection area of historically preserved part of Prague – inside the dark-red borders. Part of Prague 3 also falls within the area of the historical zone, which is the zone surrounding the historical city centre – the reservation. This enlistment was confirmed and set-up by Regulation No. 10/1993 and it also requires obeydance of certain rules and principles. The mission of the historical zones is explained in Article No. 2 of the Regulation. It states that their goal is to preserve and permanently protect the culturally-historical and architecturally-urbanistic values in the selected parts of the capital city of Prague. It also sets more strict rules for reconstruction and building of new objects within the area. Finally the Regulation sets, that all the build-up objects need to lead to aesthetical, functional, technical, cultural and social improvement of the area. This is linked to the topic of the underground containers through the fact that their implementation is considered to be a build-up object which requires among other things a building permission and needs to fulfill the criteria set-up in the Regulation (Vyhláška hl. m. Prahy 10/1993).

With respect to demography, Prague 3 has 71,140 inhabitants as of 31 December 2011, out of those 35,785 men and 38,119 women. The type of build-up area differs across the district, however there are 2,900 houses, out of that 530 are family houses and 207 are prefabricated buildings, the rest forms block of flats type of buildings (Český statistický úřad, 2012). The density of population is 10,962 inhabitanst per square kilometer. If we subtracted area which is not build-up (approximately), the density would climb up to 13,106 inhabitants per square kilometer. That is quite a high number even for Prague; whichs average density of population is 2,601 inhabitants per square kilometer (Český statistický úřad, 2012).

Following the previous paragraph, several geographic pieces of information is presented for better understanding the nature of the area in question. Prague 3 spreads out on the area of 6.49 square kilometer including all its parts, whether the build-up areas or green parks. The largest unoccupied area is formed by graveyards which are spread in the middle of this district on a 0.342-square kilometer plot. Further more there are squares and parks which altogether form 1.062 km^2 areas. As was already mentioned, the type of urban development differs from the historical part of Žižkov in the East, to the family houses in the West of this district. The difference should be considered when planning the waste management system for this district and especially the distribution of sorting spots.

4.3 Waste Management in Prague 3

Based on the related pieces of legislation (Act on Waste 185/2001 Coll.), once a person throws out a piece of trash, whether into public dustbins, containers or small bins, the capital city of Prague becomes a so called “originator“ and therefore also the owner of the waste, and is thus responsible for its further treatment. This means that it is entiteled to ensure its collection, transportation, separation, usage and disposal (portál hl. m. Prahy, 2011). This is also in accordance with the EU Directive 2008/98/EC Article 14 where it is set, that “*In accordance with the polluter-pays principle, the costs of waste management shall be borne by the original waste producer or by the current or previous waste holders*.“

Within Prague, the municipal waste is sorted into several groups: mixed waste, plastics, paper, glass – clear and mixed, bulky waste, hazardous waste, metals, biological waste and cardboard packagings from beverages. All these commodities can be groupped according to the way they are collected. Therefore, in the following part, individual system is introduced including the relatively newly implemented underground containers.

4.3.1 MIXED WASTE - CONTAINERS AND DUSTBINS

Providing of containers and dustbins of a corresponding volume is ensured by the owner of the real estate according to Regulation (Vyhláška 5/2007). Hence each house, whether it is further divided into flats or it is a family house, needs to arrange their own dust bin which is located in front or very near to the front door of the property. The dustbins are collected regularly, so we are talking about a pick-up system where inhabitants have the waste disposal spot at hand, or only few meters away from their home. Individual inhabitants of the house are contributing on a monthly basis to the fee for collection of the containers. As long as the containers and dustbins are close to the houses, the disposal is easy for the inhabitants. Sometimes a different situation occurrs with relation to separation of plastics and other reusble materials.

4.3.2 WASTE SEPARATION - STANDARD CONTAINERS

Collection of the pre-sorted municipal waste such as paper, glass, plastics and cardboard packagings from beverages are carried out by providing containers on special spots spread across the area of Prague 3. The collection of containers located at these spots is operated by one of the four companies, AVE CZ odpadové hospodářství, s.r.o. (Cihelka, 2006).

Originally, only so called “standard containers“ (name for purpose of this thesis) were used to ensure provision of places where people can throw away municipal waste they separated at home. This system is still prevalent in most places in Prague 3, however, there is a shift to the underground containers. For now, standard containers are introduced, the underground ones follow in the next subchapter.

The standard containers are placed on strategically chosen places to cover the whole area and to be approximately evenly distributed in order to maintain the walking distance on average the same for all inhabitants of Prague 3. The walking distance is said to be approximatelly 106 meters from person's front door to the sorting spot where municipal waste determined to be further used can be disposed (EKO-KOM, 2011b). Also there is a different measure how to determine the allocation of sorting spots, it can be done according to a number of people per one sorting spot. This is determined to be 200 people per one sorting spot in a family houses build-up area, and 500 people per one sorting spot within a densly populated urbanistic area (Pražské služby, a.s.).

Hence this system can be called a bring-in system where individuals have to actively participate and be willing to throw the waste into specific containers. These are for better identification often distinguished by colors, where yellow containers are for plastics, blue for paper and green or white for glass – mixed or clear, respectively. Cardboard packagings from beverages are supposed to be collected in black containers with an orange lid. Their volume is usually 1.1 $m^{3.}$ Sometimes combined containers are utilized for glass where the container is divided into two separate chambers with two individual drop-in holes. For illustration of the most common types of containers and dustbins, please see Picture 1 (Pražské služby, a.s.).

Picture 1 Overview of standard container and dustbin types

Source: Pražské služby, a.s.

The collection of biodegradable compounds of waste was left aside due to the fact that the provision of containers for this type of waste does not fall under the same conditions. Unlike the containers for collection of pre-sorted waste, the biocontainers have to be ordered and paid extra by owner of the property. It is not included in the waste management system which is ensured by the municipality, but each owner of a family house or eventually a block of flats needs to decide whether he/she wants to have this possibility of waste sorting. If so, then he/she needs to order the dustbin of a brown color and also the pick-up service on his/her own and pay for it accordingly. This management does not contribute to expansion of biowaste sorting, even though it forms almost one half of the municipal mixed waste and its separate collection would significantly help to reduce the amount of waste disposed by landfilling or incineration.

These types of containers are a common type in most places and cities across the Czech Republic. During their utilization, their pros as well as cons were identified. They are mobile, which makes them easy to shift and replace in case they are damaged or need to be reallocated. Their acquisition costs are very low, one standard container may cost between 5,000 to 25,000 CZK (Vaňous, 2010), which is a relatively acceptable and feasible amount with the number of containers needed to cover the area of Prague in required density. Also the operational costs are low because no special vehicle is needed for collection. The lid is usually big within containers for plastics, paper of cardboard packagings, so it is easy to fit in even bigger pieces of trash. The drop-in hole for glass is either round (the size of a bottle), or rectangular about 40 centimeters high and narrow for drop-in of sheets of glass. Also they do not require any building or construction work, they are purely placed on the selected spot which keeps their price relatively low. However, as long as these containers are not fixed at one place, they can be easily moved, hence the risk of their damaging is relatively high; also they are an easy subject to vandalism. From the aesthetic point of view, they are rather seen as intruding as the trash is visible if the lid is not closed. Also one can smell the stink from trash when passing around the sorting spots, especially in warm summer months.

However, a new type of containers was introduced in Prague 3 as a tool for separation of glass, plastics, paper and lately also cardboard packaging from beverages. These were suggested to be used basicaly as a reaction to deficiencies of standard containers. A more detailed introduction of this type of containers, the plan for their implementation, the hitherto experience with the underground containers and the related issues are discussed in the following part forming also a basis for further calculation.

4.3.3 Waste separation - Underground Containers

On 9 December 2009, there was a press release on the web pages of Prague 3 announcing that "Prague 3 moves containers for separated trash underground" (Sotona, 2009). A new type of containers was introduced with high expectations of improvement within the waste management system.

Prague 3 was not the first municipality to introduce such a type of container. It was firstly build in Brno in 2006 where these containers were implemented in the historical part of the city centre to prevent from lowering of the aesthetic surrounding of the containers (Mašek, 2006). Following this step, also other cities in the Czech Republic, such as Uničov and Šumperk have adopted this method. The capital city was not lagging behind and Prague 1 district has also adopted few pieces of such containers because of the very same reason as in Brno. Since Prague 1 area is situated in the historical reservation area, the usage of standard containers was perceived as aesthetically intrusive. So in the most frequent places, underground containers were used with combination of standard containers which are, however, unlike in Prague 3, placed directly in the houses, in the house passages and small yards which are typical for the houses in the city centre. Therefore, the trash in the historical reservation part of the city has totally disappeared from the view – either into the houses or under the ground.

On a question why are not underground containers used broadly also for mixed municipal waste Mr. Němec (2008, p. 17) says that an economically acceptable collection of underground containers requires a special vehicle with compressing, skip loader and its own hydraulic arm. Such a vehicle can be effectively used only with a sufficient number of operated spots. And that is actually what distinguishes Prague 3 from other municipalities. It is the fact, that it was the first district that plan implementation of the underground containers on 91 % of places. Mr. Sotona, the press offices of Prague 3 stated, that the plan is to replace the current (as of 2009) 147 standard collection spots by 89 underground spots and retain only 14 spots with standard containers.

There are several manufacturers of such containers. For the utilization within Prague 3, containers produced by company SSI Schäfer were selected. This is the “OR” type of underground containers who are either placed in a row or form a so called star shape. These containers have usually volume of 3 m^3. This volume is located in a form of a container underground and plus there is a small part with a drop-in chute above the ground. The size of the container which is located under ground is 1.9 meters high with width and depth of 1.25 meters. The container is made from a steel zinc-coated sheet. For illustration see Picture 2 (SSI Schäfer).

Picture 2 A) Underground containers spot in Prague 3; B) Underground containers: cross-section.

Source: own photograph

Source: SSI Schäfer

The company EBM – Expert Building Management, s.r.o. ensures for the municipality of Prague 3 the project, engineering, planning, issue of the building permission, delivery of the underground containers and the construction works. The implementation of these containers is quite a demanding process – unlike with the standard ones. It all starts with the preparation phase including selection of the right locality, elaboration of project documentation and its discussion with municipality and the management of engineering networks since these need to be sometimes moved or rebuild when the underground containers are build. The realisation phase follows starting with getting the build permisison, then actual building of the containers follows and finally technological loading test of the equipment. The third oprational phase consists of statutory approval, handover for utilization to the municipality and waste collection firm, and last the containers are put into service (EBM, 2012). For illustration of some of the phases see Picture 8 in appendix.

The expected benefits of the underground containers are according to EBM (2012) a bigger volume of the containers, where we compare $3m^3$ versus $1.1m^3$ with the standard containers. Therefore, even though less sorting spots are planned, the absolute volume will increase approximately by 67 %. This number was obtained by assumption, that before the implementation of the underground containers, there were 147 sorting spots. Each of the spot consisted of 3 – 4 containers. The assumption is that in 20 % of spots, the container for cardboard packagings is missing, and in 7 % there are 2 containers for plastics. Hence:

Within 147 standard container spots, the volume of an average container spot equals:

(1.07 plastics con. + 1 paper con. + 1 glass con. + 0.8 cardboard con.) = 3.87 containers
3.87 containers x 1.1 m^3 = 4.257 m^3/spot => 147 spots x 4.257 m^3 = **625.8 m^3**.

Within the planned combination of 89 underground spots and 14 standard spots, the volume is:

(1 plastics con. + 1 paper con. + 1 glass con. + 0.7 cardboard con.) = 3.7 containers
3.7 containers x 3 m^3 = 11.1 m^3/spot
89 underground spots x 11.1 m^3 + 14 standard spots x 4.4 m^3 = **1,049.5 m^3**.

The increase from 625.8 m^3 to 1,049.5 m^3 is the 67 % increase.

The next argument for implementation of the underground containers is linked to the previous one. Since there less spots of mostly bigger volume, the underground containers do not need to be collected that often. Therefore the operational costs might be lower. However, this might be questionned in several ways.

Firstly, the trucks which collect the waste from the underground containers need to be equiped with special technology to be able to manipulate the container, and the acquisition of this type of container is probably higher then of the current ones which are already present. Moreover, as Sokol (in Vaňous, 2010) states, the new trucks with the hydraulic hand do not possess the hydraulic press as the current trucks do. Therefore, full capacity of collection trucks is not used which leads to inefficiency and lower the possible decrease of operational costs.

Secondly, by decreasing the number of collection spots, the walking distance will prolong for many citizens of Prague 3 and also the number of citizens per one container will increase. Currently it is set that there should be 200 people within the family house build-up area and 500 people per one spot in a densely populated area. This number takes into account also the walking distance, at least conceptually. For simplicity and also due to the lack of data determining how many spots are in which type of build-up area, an average number of inhabitants per one sorting spot will be calculated as follows:

Originally:

70,140 inhabitants / 147 standard spots = **477 inhabitants/spot**

New plan:

70,140 inhabitants / (89 underground + 14 standard spots) = **681 inhabitants/spot**.

From the computation it is clear, that the number of people, in other words the amount of trash to be put into containers at one spot will significantly increase if the plan is followed and the walking distance will be longer. As Čtvrtečka (in Vaňous, 2010) says, in Náchod city they prefer the standard containers due to the fact, that it is ideal when the sorting spots are no further than 100 meters from citizens' front door. If the distance is longer, people tend not to use the containers.

Also, due to the special manipulation, there is an increased danger of harm. As Vaňous (2010) writes in his article, for example in Hradec Králové on Masaryk's place, the containers are withdrawn from the ground and carried over the parked cars to reach the truck.

One of the main reasons that were mentioned to justify the implementation of underground containers is the increased aesthetics. As Ježek (2010) says, the underground containers are a progressive architectionical solution of waste management. Vaňous (2010) adds that it is an elegant solution for historical places. The the containers do not disturb the characteristics of the surrounding and also conform to the requirements of the preservationists. Still, as nothing is perfect, also the underground containers proved not to increase the aesthetics in 100 % of cases so far. Often there are bags with trash and cardboard boxes next to the above ground of the containers (see Picture 9 in appendix). This can be so far explained by two reasons. As Sokol (in Vaňous, 2010) stated, when somebody lays a bag with trash next to the container and does not throw it in, others do not doubt whether the container is full or not, they simply lay their bags next to the original one. This is more of a psychological issue when people do not bother to open the container and have a look inside. This was observed also during the field research, for illustration see Picture 3 on the next page.

On the other hand, often it is simply not possible to throw the trash in as the drop-in holes are really small (Sokol in Vaňous, 2010). Based on the measurement it was found that the size of the drop-in hole is 39 x 22 cm (see picture Picture 10 in appendix). The justification of the size is that if the drop-in hole was bigger, people would throw in bigger pieces of waste, thus the volume would not be used effectivelly and the containers would be collected half full. Hence it is advised to adjust the bigger pieces of trash, e.g. cardboard, by cutting or tearing so that it fits the hole. However, as the cardboard can be cut by scissors, for example a sheet of glass is very hardly adjustable without increased danger. The originally included special drop-in holes in the shape of glass sheet are not included within the underground containers. Therfore people tend to leave the glass next to the container, which is not the safest possible solution (for illustration see Picture 11 which is included in appendix).

If this adjustment is not possible, people should dispose the trash in collection yards or large-volume containers (EnviWeb, 2011). Availability of these services (described below) brings rather controversial dispute where people rather than travelling to the collection yard or waiting for the large-volume container, throw the big pieces of waste to the mixed waste, or simply lay them next to the containers.

Picture 3 The messy surrounding of the underground containers compared to the free space inside.

Source: own photograph

Another remark is on the aesthetics. Only one part of Prague 3 area lies in the historical zone part, not even in the historical reservation. The implementation within this area is understandable. But as was described, the area of Prague 3 also consists of build-up area with family houses of prefabricated houses where there is only little historical value present. In such places, the application of the underground containers can be rather disputable and will be considered in the recommendations chapter.

Among aesthetical improvements was also mentioned lowering of the noise when throwing-in the glass and less smell especially in summer months, as long as the underground containers are clossed all the time. This proved to be true and a real improvement when dispose the trash.

And last, but not least, the underground containers are supposed to lower the vandalism and plundering of the current containers (Sotona, 2009). This is true to the extent, that the content of the containers cannot be reached through the drop-in hole unless from the very top when the container is full. Also the containers have self-extinguishing system so neither them, nor the trash inside can, can be set on fire. And also these containers cannot be moved away and misused.

At the time when this thesis was written, there were 19 underground sorting spots installed. With respect to that, the observations were carried out and thus are further introduced in one of the next chapters.

4.3.4 Waste separation - Collection Yards and Large-volume Containers and Mobile Collection of Hazardous Waste

So far, the way of disposal of mixed waste and of reusable commodities such as plastics, paper, glass, biowaste and cardboard packagings from beverages was introduced. However, there are many other types of waste which are not supposed to be thrown away into any of those containers, such as hazardous waste, bulky waste and many others. Therefore, there are other three ways of collection within the Prague 3 area. These are collection yards, large-volume containers and mobile collection of hazardous waste. Each of them is shortly introduced below.

As of July 2012, there are 17 collection yards within the area of Prague which are available for all inhabitants of Prague, no matter where they live. Moreover there are 5 collection yards designed only for citizens of certain Prague districts, namely one yard for Prague 4 and 4 yards for Prague 6. Most of the yards are located on peripheral parts of the individual districts (Portál hl. m. Prahy, 2012). Within Prague 3, there is one collection yard located in Malešická Street near the borders with Prague 10 district. See the location of individual places on Picture 12 in appendix.

The collection yards are intended for disposal of bulky waste such as furniture, wooden waste, wastes from upkeeping of grass and gardens. Further all kinds of hazardous waste as well as metals, scrap electronics such as old refrigerators, freezers, television, radios, stoves, computers etc. are collected from inhabitants of individual districts. Last but not least, also plastics, glass, paper and cardboard packagings from beverages are collected there, so especially if one posesses a bigger amount of these commodities or ones of bigger volume, here they can be disposed (Portál hl. m. Prahy, 2012).

The collection yards are also presented as a part of separate waste collection system. However, realizing there is basically only one such a spot within the area of Prague 3 (based on the information on the map – Picture 12), probably there are other two in other districts within still acceptable distance, the number of yards is not sufficient and also not accessable for all inhabitants. They are often hard to reach without car or any other motor vehicle and especially disposing bulky waste using public transport might be rather impossible. For this case, other methods of waste collection are operated.

The large-volume containers are irregularly drawn near area with higher concentration of inhabitants. The dates and places are announced by the municipality government sometimes several months in advance. The containers are available for four hours in the afternoon and sometimes during the weekend. These are intended for disposal of bulky waste from households, unlike the hazardous waste (refrigerators, monitors, paints, drugs, grass and other parts from green cultivation, old fluor lamps etc.) (Portál hl. m. Prahy, 2011). This method is literally a moving of the collection yard close to the people, with a limited offer of services, but still better than nothing.

The third method is supplementing the large-volume containers as it is purely intended for disposal of hazardous waste. There are two routes operated within Prague 3 each having eight stops; these are operated four times a year and at each stop there is 20 minutes time to bring-in whatwever hazardous waste people need to dispose. Again, this number of terms is not high and people have to plan to visit the stop, but still it saves them time as they do not have to go to the collection yard (Portál hl. m. Prahy, 2011).

4.3.5 Returnable Packagings and Other Commodities

Another minor type of waste disposal method is implemented through stores, schools and municipal offices where people can return used batteries and monocells. Also in the drug stores people can dispose of unused drugs and mercury thermometers (Portál hl. m. Prahy, 2011).

It is possible to use the buy-out service of flasks from beer and bottle crates. For each bottle disposed in this way, person is given CZK 3 discount voucher from the shopping. The CZK 3 amount is included in the price of the beer bottle at purchase and is therefore returned in this form of an advancment which forces people to return the bottles so that they could be further reused. However, in some countries (e.g. Norway), this way of handling bottles is further spread on buy-out of metal cans from beer and soft-drinks as well as PET bottles. This is still not the case in the Czech Republic, nor is it planned.

Also recyclation of electronics is supported by adding extra price on purchase of an electronice device. This fee is so called Charge on historical electrowaste (in Czech PHE – Poplatek za historický elektroodpad), also called recycling charge. Its rate is calculated based on how difficulat and demanding it is to dispose the waste, so for example the charge for fridge is over CZK 200, whilst for an iron it is CZK 3. The idea is that when buying a new piece of electronics, theoretically the old one you hold needs to be disposed. The sellers of electronics are therefore obliged to accept the old piece of electronics for you, deliver it to a place where it can be disposed, reused or recycled and also to allocate the amount you paid within buying the new appliance as a contribution to disposal of the old piece of electronics. This helps people to get rid of the unused appliances directly when the new ones are delivered, so they do not have to care about how to deliver for example the old fridge to the collection (Asekol, 2012).

4.4 Internal Costs and Benefits

In this chapter, the inputs for the linear programming (LP) model are computed and estimated. There are several basic premises followed when doing the computation; these are explained here. Firstly, it is necessary to consider the unit of measurement. This was chosen to be costs/benefits per one container per year. Another option would be to measure the costs and benefits per sorting spot, however, especially as long as the number of containers within the individual spots may differ a lot, the results would not be comparable. On some places of standard containers, there is one container for each commodity; one for plastics, one for glass and one for paper. Few years ago, the containers for cardboard from beverages started to appear on some spots. Also, where there is a high density of population and there is enough space, there might be for example two containers for plastics at one spot. The assumption made for further computation is, that at 7 % of standard spots there are two containers for plastics, and at 80 % of standard spots there are containers for cardboard. With the underground containers, the 19 spots that were built at the time of the research consisted only of three containers for glass, paper and plastics. However based on an observation and official announcement, the newly built spots (70 of them according to the plan) will consist only of 4 containers, at all of them the cardboard beverages container will be included.

Next issue is the time span of the project. To be able to compare the costs and benefits obtained, the scenario of computation is that both projects are started from the very beginning in the year 2009. However as long as the implementation time is different with the standard and the underground containers, the total period of time mentioned is different. However, to make the results comparable, the costs/benefits per one container are then recalculated to the EAB/EAC value. With the standard containers, the implementation is not hard and does not take long as there are no build-up works necessary. Therefore the suggested period of implementation is two years when all standard containers should be at their place. This type of container falls under the second depreciation category where the time for depreciation is 5 years. Therefore the costs are computed from year 2009 until the year 2015 when the last container should be depreciated to zero. With the underground containers, the implementation is much more demanding in terms of time. Therefore there is a plan suggesting the total build-up within 10 years. This type of container is classified into the third depreciation category, so the time is 10 years. The life span is therefore since year 2009 until year 2028.

As was explained, to obtain comparable results for individual types of containers, it is necessary to calculate first the NPV and then the EAC/EAB. Input for this calculation is the amount of costs or benefits within each year, but also a discount rate. This was computed to be 3.94 % assuming that the real interest rate is 1.5 % and the inflation coefficient is 2.4 %. This rate was used for calculation of both costs as well as benefits.

4.4.1 Cost and Benefit Categories

If all the real costs and benefits should have been considered, then for example the benefits from the separated and recycled waste would have to be considered in the computation. However, the proposed change from standard to underground containers is an innovative change which assumes improvement mainly in aesthetics and it does not expect any increase in the amount of waste actually separated. The similar situation would be with the produced electricity and benefits from its sale. As long as these could be the same because it does not depend on the type of container, it is not considered. Therefore benefits and costs that are the same no matter type of container used are not considered in future computation.

Articles by Chang and Lin (1997) and by Bohm et al. (2010) served as a guide for defining the cost and benefit categories to be taken into account. From those which are applicable for this thesis, four cost groups were formulated. Firstly it is the investment costs. Under these we understand in case of the standard containers the price of one container; with the underground containers it is the price per one container plus the build-up costs. The next cost category is the machinery, after that the administration costs and also the operational costs resulting from collecting the waste from the container.

The applicable benefit is in this case expressed based on the willingness to pay which reflects the suggested improvements brought together with the underground containers. With the standard containers, there are no benefit categories identified. It resulted from the fact, that the reason for this new type of containers was the currently quite bad situation and environment due to the standared containers. Therefore the underground containers should only improve the situation; what do respondents think about that is captured in the WTP value.

4.4.2 Net present value (NPV) of Internal Costs: Standard Containers

The price of one standard container is quite low; it is estimated to be roughly CZK 7,000 (AB-STORE, 2013). The value of administration, machinery and operational costs was not easy to find. Though a direct question was sent to the both municipality as well as the company operating the municipal waste management in Prague 3, none of these institutions was willing to share any information regarding costs and benefits. Therefore data from the internet are used. ENVIS (2009) stated that the total costs regarding these two categories were in year 2009 CZK 1,005,284,000. Prague 3 in this year produced 5.7 % of all Prague's waste. Therefore the corresponding proportion of these costs was CZK 57,301,188 for Prague 3.

As was said, the number of containers at one spot differs. When following the percentage estimates from previous chapter, we can assume that within 147 standard container spots, there will be in total 580 containers divided for commodities in the following way: 150 paper containers, 150 glass containers, 160 plastics containers and 120 cardboard containers. Therefore, the operational, machinery and administration costs per one standard container are CZK 98,795. This category will be for simplification called the operational costs.

In the first year when half of the containers are placed, 60 % of the operational costs were charged taking the 10 % extra for initial expenses. The same was estimated for the second year. Between years 2011 and 2015, the full amount of operational costs is planned as there are already all containers operated and no new machinery is necessary to be purchased. Summing up all the costs in the whole project life, this leaves us with CZK 359,327,366. Applying the discount rate, the discounted internal costs are CZK 305,302,184. Dividing this number by the sum of the discount factors, which is 6.0162, the equivalent annual costs for all the containers are CZK 50,746,040. Per one container per year this gives CZK 87,493. This number includes the operational costs in individual years as well as the investment in the very beginning. This amount will be recalled later on when building the simplified LP model. For computation please see Table 4 in appendix.

4.4.3 Net Present Value (NPV) of Internal Costs: Underground Containers

One can imagine, that if it was hard to find at least a little relevant and realistic numbers with respect to costs related to the standard containers, the situation with the underground containers is even worse. With the standard containers, at least the investment price is easy to find as long as basically anyone can buy the container no matter the use. However, the underground containers represent much bigger investment related to project and construction plans, so to find the exact numbers was not easy to do even though this is partly invested by the money from taxes, so in fact inhabitants of Prague 3 should have the right to get the information.

The investment costs were calculated based on an amendment agreement to a contract about the build-up of the underground containers. Even though the original contract was not found on the internet, the amendment contains much relevant information. The amendment was signed in April 2012 and it modifies the subject of the original contract to a delivery and project documentation for 50 underground spots where each spot consists of four containers. The total amount of this contract without VAT is CZK 132,850,940. From this amount it can be computed, that the price per one 4-container spot is CZK 2,657,019 and price per one container is CZK 644,254.7. This number is much higher compared to the initial investment regarding the standard container. As is explained in the amendment, this amount includes the delivery, project documentation and build-up of the containers, so no other initiation costs are considered (e-zakazky, 2012).

Further on, the operational costs were not found as expressed directly, so these will be considered the same as the costs of operating the standard containers and arranged based on some facts. The machinery might increase the costs of operating the underground because a special truck with a hydraulic arm is necessary to be purchased (Kotoulová, 2012, p. 12). The administration costs should be the same and the operational costs might be higher in terms of wages for the employees. Based on the article it is said, that the underground containers will be emptied at night, so extra pay for night shifts need to be computed. In total, the operational costs are estimated to be higher by 5 % compared to the standard containers. This gives us a value of CZK 103,735.

When the cost categories are estimated and computed, the NPV of the internal costs with the underground containers can be computed. Employing again the discount rate of 3.94 % and the time period of 20 years, as explained above, the total NPV is CZK 2,290,759,520. This number is a sum of all costs incurred in individual years, which means the investment and build-up costs, operational costs and plus some reserve especially when the underground containers are implemented. Again, to get a comparable amount of costs for one year, the equivalent annual costs are computed as the total NPV divided by the sum of discount factors which gives us CZK 167,604,235 per all containers per year. Divided by 337 – the number of underground containers, we get the annual discounted internal costs per one container which equals CZK 497,342. This number will be later used in the simplified LP model which excludes the environmental/external benefits. For illustration of computation see Table 5 in appendix.

4.5 Environmental Costs and Benefits

The second important and distinguishing cost/benefit categories are the environmental/external costs and benefits. As was already explained in the methodology part of the thesis, to express the environmental costs and benefits in numbers is rather a complicated issue as the data are not directly obtainable. Hence, a non-market valuation method is introduced at least conceptually, the contingent valuation method. If it should have been carried out in full extent, it would be really resource demanding. Therefore, two methods are used to get at least estimates of the values needed. Firstly, data analysis was carried out to use results from other pieces of research on related topic. Secondly, within the questionnaire survey one question was also asked about the environmental evaluation. The results are presented in the following paragraphs.

4.5.1 WTP – Data Analysis

To gather data about respondents' willingness to pay, several research articles were analyzed. The aim was to find similar research areas focused on waste management, if possible separate waste collection systems. Altogether, four articles and their results are presented. The articles were written under different conditions as the years and currencies were different. To make the data as comparable as possible, the WTP researched was recalculated. Firstly, the exchange rate between the currency in research and CZK was found and the WTP was expressed in CZK. Next, the average inflation rate was calculated for the period between year of the research and year 2012 when data for this research were gathered. The present value was calculated where the percentage was the average inflation rate, the number of periods were the number of years between the original research and year 2012, and the amount was the recalculated WTP, now in CZK per month.

A second comparison is made based on the gross average monthly salary value. This value was obtained (UNECE, 2013) for the particular country and year of the research. Then, the WTP value was divided by the gross average monthly salary value to find out the share of income people are willing to contribute.

The first article analyzed is written by Basili et al. (2006). A new garbage plan was enacted in the province of Siena in Italy, and the idea behind this piece of research was to evaluate the costs and benefits of the new plan assuming that the WTP reflects the value which the community places on having better environmental quality. Firms and households were asked separately through a detailed questionnaire. The result obtained by the authors for the household population was the mean WTP of EUR 3.07 per month. After recalculation (as explained above), the value as of 2012 is equal approximatelly to CZK 72 per month. The original value EUR 3.07 equals to 0.14 % of average gross wage in 2006 in Italy.

The second article by Sterner and Bartelings (1999) "*focuses on the determinants of total household waste and the effects of unit price payments combined with better access to recycling possibilities*". In context of this, they also determined the, as they name it "willingness to actually get involved" which is very much relevant to the context of this thesis. Their research was carried out in year 1999 and the average WTP they obtained based on their questionnaire was 400 SEK per year. This amount corresponds to CZK 99 per month as of 2012 prices. The monthly amount in SEK currency equals to SEK 33.33 which was in year 1999 approximately 0.17 % of average gross wage in Sweden.

The last analyzed article which best fitted this diploma thesis provided two other values, one based on the research itself and other value which was mentioned by the authors also to compare their results. The article was written by Tiller et al. in 1997 and its main goal was to analyze the economic feasibility of drop-off recycling in rural and suburban areas. Though, geographically the results are not closed to the subject of this thesis since the research was carried out in Tennessee in the USA, the focus on drop-off recycling and the measuring the WTP for this waste recycling method made it still usable.

From the results by Tiller, the WTP for the suburban area was used. They got the mean WTP of USD 11.74. this amount corresponds to CZK 192 in 2012. We can see that this value is higher than in previous examples where the values were CZK 99 and 72. The share of the USD 11.74 on the gross average monthly wage of the inhabitants of suburban areas was 0.42 % which is also a higher rate opposed to 0.17 % and 0.14 % from previous articles.

Within this article, some other WTP estimates were presented for comparison. Lake, Bateman and Parfitt (accessed in Tiller, et al., 1997) carried out their research in the United Kingdom and it was focused on estimation of WTP for a curbside recycling pilot program. The results showed that the mean WTP was GBP 35.69 per year. This is equal approximatelly to CZK 79 per month in 2012 prices. The share of this amount on the average gross monthly wage in the U.K. was 0.2 %.

As it was explained in the methodology, these figures are included for the sake of comparison with other countries and mainly with more profound pieces of research which are based on large data samples. However to have the input from the population in the Czech Republic gives better understanding of people's attitude in local conditions. As long as peoples' focus on environmental issues might differ significantly in various countries, the data obtained from a small questionnaire survey are still seen as relevant as they capture the present and geographically more focused conditions. Therefore, in the following chapter the information from the questionnaire survey are introduced.

4.5.2 WTP - Questionnaire Survey Results

The questionnaire survey and its results served as a source for two chapters of this thesis. One is the chapter on the willingness to pay and the second chapter is the qualitative analysis which follows. In the survey, there was one main question which asked directly how much are people willing to contribute in addition to what they already pay on the monthly basis, 5 options are offered to choose from.

However, prior to this question from which's answers the results for this chapter are concluded, there was supplementary questions. It asked based on peoples' knowledge of the underground container, whether if they were supposed to choose the container type which will stand at the spot where they currently sort waste, which type of container would they choose. On this question, 45 % of respondents answered that they would prefer the standard containers and 55 % stated that they would choose the underground container. Only from this it can be concluded, that the preferences of the underground containers are almost fifty-fifty compared to the standard containers. This ratio does not give strong advantages in favour of the underground containers.

As was mentioned before, the next question suggested a scenario where the municipality would communicate that the build-up and operation of the underground containers is very costly and thus it asks for people's opinion on how much would they be willing to contribute (WTP) to pay more on a monthly basis then they are already paying for municipal waste handling. Again there were five possible answers. The first one was that the individual does not want to contribute; rather he/she keeps the standard containers. The other five options were graded starting from option up to CZK 50 per month, then up to CZK 100, up to CZK 200 and more then CZK 200. It was interesting to see that out of the 54 % of respondents, 41 people, 17 people are willing to contribute, this makes 41 %. This shows that the remaining 59 % were more or less satisfied with the underground containers as long as money was not in question. When they were asked to pay for it, the standard containers were sufficient. 41 % saw the underground containers as worth contributing and the remaining 24 respondents are not willing to financially participate even though they like the underground containers more.

Regarding the level of contribution, out of the 17 respondents, 10 were willing to contribute up to CZK 50 per month; this corresponds to 59 % of contributors. 7 respondents' WTP was up to CZK 100 per month. No respondents from those who chose the underground containers were willing to contribute more than CZK 100 per month. Howere, there were some respondents who chose the standard containers, but still they would be willing to financially contribute. Reason for this may either be a misunderstanding of the question asked where there was explicitely said that one should choose the level of contribution only if he/she chose the underground containers in the previous question. Or the reason might be that those respondents are willing to contribute because the issue is consdiering focus on recycling and thus environmental improvement no matter the container type. Therefore they also expressed their level of WTP for the containers. There were 4 such respondents out of the 33 who seleted the standard containers. One was willing to contribute up to CZK 50 per month, two were willing to contribute up to CZK 100 per month and one of them was even willing to contribute up to CZK 200 per month which was the option that was not present by the supporters of the underground containers. In total, 28 % respondents were willing to financially contribute above their payments for municipal household waste fee.

As mentioned in the beginning of this chapter, two methods are used to reach more accurate results and to compare whether the results obtained from the questionnaire survey are similar to those obtained in other countries. To do that, the contribution amounts, thus the CZK 50, CZK 100 and CZK 200 will be also expressed in terms of the share on the average gross monthly wage in the Czech Republic. This was in year 2012 when the data were gathered CZK 24,451 (CZSO.cz, 2013b). Also, the highest range of the interval will be used. Out of the the lowest level of contribution represents 0.2 %, the contribution of CZK 100 represents 0.41 % and the contribution of CZK 200 which occurred only once is approximatelly 0.82 % of the average gross monthly rate in the Czech Republic in 2012.

Comparing these figures with the ones obtained by data analysis, we can see that the numbers are in the same place value of digit. They vary from 0.14 % in Italy to 0.82 % in the Czech Republic. But on average the percentage values obtained by data analysis reach the value of 0.23 % of average gross monthly wage. That would correspond to CZK 56 which is between the two most often suggested values for contribution. We can say that the results of both methods are comparable and that no significant difference in the values was obtained.

4.5.3 Other Environmental Costs and Benefits

The improvement of aesthetics of the waste sorting spots may also bring benefits from a broader perspective, as it increases the attractiveness of the whole locality. Therefore, price of real eastates migh slightly increase as being perceived as being located in a part of Prague which is a better and cleaner place to live.

Also, as one part of Prague 3 area lies in the historical zone of Prague, it is often visited by tourists whether for enjoyment of architectonically attractive buildings, such as the Žižkovská tower, or to enjoy an evening in one of the less tourist-busy pubs or restaurants. Walking the clean and neat streets might attract the tourists more than dirty streets with litters around the containers.

The problem with vandalism could be also improved by implementation of underground containers. The plastic "standard" containers are often plundered by homeless people who search them for anything they could further use. Sometimes the containers are set on fire. By providing the non-flammable containers, the area could be perceived as a safer place to live.

Not only vandalism causes mess around the collection spots. The Czech Republic and thus also Prague lie in the moderate climatic zone, however from time to time the wind reaches higher speed and the standard containers are easily overturned or even moved from their positions. It does not happen often, but still there is the possibility. Even if it does not come to the overturning of the container, as they are often overfilled and the lid is open, the trash might be blown away by stronger wind.

Last, but not least, as long as the underground containers have bigger volume, their collection is planned on a less frequent basis. Whether this is sufficient or not the practice will show. But in theory, less frequent collection period and less sorting spots should cause less CO2 emission and noise within the Prague 3 area. All these could be counted as environmental benefits.

On the other hand, as is apparent from the qualitative analysis below, the underground containers might not always bring only positive changes. Sometimes the aesthetics is even worse as big pieces of trash are hard or impossible to fit in, also, the implementation plan counts with less container spots which would lead to increase in the average walking distance towards the containers and increase in number of people per one container spot. That might in the end cause negative effects and bring more costs.

All these benefits and costs should be counted towards the sum of the environmental/external costs and benefits. However, numerical expression of these figures is highly hypothetical and inaccurate. As long as there are negative issues as well as positive ones, the value of these external costs and benefits will be considered as cleared and will not be further considered in the computation.

4.5.4 Net present value (NPV) of Environmental Costs and Benefits

First, it is necessary to sum up on the results gained from data analysis and questionnaire survey results which provided inputs for WTP value determination. The aim of expressing in numbers the value of the WTP is that it is necessary for further use in the LP Model as environmental benefits (later to be used as negative costs). For the sake of the LP Model, a potential net present value of the total amount contributed by all citizens in Prague 3 per year per one container is necessary to be computed from these results. To do that, the data gained from the questionnaire survey results will be extrapolated on the whole population of Prague 3. This means that the share of respondents willing to contribute a certain amount will be recalculated for the whole population of the area in question. This number of people will then be expected to contribute the same amount. This will be done for the three financial amounts obtained by the questionnaire. Finally the sum of these three amounts gives us the yearly possible benefit for operating the underground containers.

However, this computation suggests that the contributions are voluntarily. As long as waste sorting is not monitored and thus is regarded as voluntary activity, in fact those who decide to contribute would be worse off because they would pay extra money for being more environmentally aware. As a result of that, the policy should then continue by offering those people the option to have the underground containers close to their homes; however a consensus by bigger units, such as block of flats, houses in a certain street would be necessary. Another option that could be made is to compute the average value of the contributions and put it as an obligatory fee for everyone. But this no longer represents the WTP concept where people can freely express the amount of contribution. Hence, the first option is counted with even though it provides approximate results, but sustains the concept of voluntary contribution.

A correlation between the amount of contribution and the respondents' average monthly income as well as education level was analyzed. However, no strong or medium correlation was found. Therefore we can say that there are other factors which play role in whether people are willing to financially participate and if so, how high is their WTP. This factor could the interest in the environment or that respondents are happy with the aesthetics of the containers.

Recalling the figures about the donators and the level of the contribution, there were 11 people willing to pay CZK 50, 9 willing to pay CZK 100 and 1 person willing to contribute CZK 200. As was said before, the upper edge of the interval will be used for the analysis as long as the benefits need to be maximized. The 11 respondents represent 14.86 % of the people who participated; this is transferred to 14.86 % of the total population of Prague 3 which is 10,571 inhabitants. Similarly with the other two levels of contribution, 9 respondents represent 12.16 %, which means 8,651 inhabitants and the one respondent represents 1.35 % which corresponds to 960 inhabitants of Prague 3.

The people who contribute CZK 50 per month would in total pay CZK 600 per year. Those, who contribute CZK 100 or 200 per month, pay in total CZK 1,200 or 2,400 per year, respectively. Extrapolating these numbers on the whole population of Prague 3, we get that the 14.86 %, in other words 10,571 inhabitants contribute CZK 6,342,842 per year. The 12.16 % of the CZK 100 contributors pay in total CZK 10,380,749 per year and the last 1.35 %, thus 960 inhabitants pay CZK 2,304,936 per year. Summing up all these figures we get that 28 % of the population, hence 20,182 inhabitants contribute alltogether CZK 19,028,527 per year. To obtain the amount of contribution per one container per year, logically it is necessary to divide this total contribution number by the number of containers.

The number of underground containers to be built in the area of Prague based on the plan from 2009 is 89 underground sorting spots should be built. The spots build in the beginning of the project consisted of three containers, at the time of the research where 19 spots were observed, all consisted of the three container chutes. However, since that time, the newly build spots should already have 4 containers. Therefore, the total number of containers planned is 19 spots with 3 containers, that is 57 containers and 70 spots with 4 containers each, that is 280 containers. Alltogether this gives us 337 underground containers. Now the yearly contribution per one container can be determined as CZK 19,028,527 / 337 = 56,464 CZK.

The timeline of the whole implementation project is again crucial here to consider several facts. To get the present value of the environmental benefits, the NPV needs to be calculated for the sake of more precise planning. Also not all underground spots are built within one year, so the level of contribution needs to be arranged according to the number of containers build in individual years. This follows the assumption that only those who can already use the containers pay for it. A time plan is suggested based on articles read about the intention of Prague 3 in how the implementation should be rolled-out. In year 2009, one spot of three containers was built, in year 2010, 4 spots with 3 containers each were built and in year 2011, 11 underground containers spots were built. If the goal of building 50 spots till the end of year 2014 should be finished, then we can assume that in year 2012, 3 other 3-container spots are built (based on reality) and 9 4-container spots. In years 2013 and 2014, 11 underground 4-container spots should be built. At the break of years 2012 and 2013 we can already say, that this plan will not be fulfilled, however, to keep the computation consistent, the plan is used as presented. The remaining 39 container spots are suggested by the author of the thesis to be built in four upcoming years. Thus between years 2015 and 2018, 10 spots are planned and for the last year it is 9 spots due to the closure of the project.

Now the computation of the NPV needs to be recalled so that we have the value of environmental benefits for the starting year of the project. Therefore, the amount CZK 56,464 is applied as an environmental benefit according to the number of the containers built in that year. For illustration of computation see Table 6. The total number of years for the project is considered 20 years where in the first 10 years, the implementation should be completed and the following 10 years are considered as a time when the last container spots will be depreciated from the accounting point of view. However, the lifespan of these computers is probably planned to be much longer. Again, for the sake of consistency, all computations related to the underground containers are carried out with respect to a 20-years project.

The total NPV computed based on the successive implementation of the underground containers was computed to be CZK 172,876,684 with the discount rate 3.94 %. As was mentioned in the methodological part, to get a comparable value for all individual years, the NPV was recounted to the total EAB (Equivalent Annual Benefits). This number was obtained by dividing the total NPV by the sum of discount factors within the 20 years. After this computation, the number of CZK 12,648,584 was obtained which equals the total EAB. Finally as we are interested in the EAB value per one container, the total amount is divided by 337 which is the number of the underground containers to be built within the 10 years. We get a number CZK 37,533. This amount can be subtracted from the internal costs value which was obtained above. After doing this, the EAC value for one underground container per year is CZK 459,809. This amount will be recalled in the following chapter.

4.6 Simplified Linear Programming Model

The linear programming (LP) models help the individual to minimize or maximize a so called objective function having presented specific constraints which limit the minimization or maximization. In this case, the minimization example is used in order to minimize the costs associated with investment and operation of the containers. There are two models built which have the same constraints, but the objective function differs according whether the environmental benefits are included or not. This show how big the amount of the benefits (expressed in WTP) is compared to the significantly higher investment costs related to the underground containers. As was computed above, the purchase price of a standard container forms only 17.6 % of the purchase and build-up price of one underground container. The linear programming model holds these constraints and computes the optimal value for each variable with costs minimized.

4.6.1 LP Model Excluding Environmental Costs and Benefits

The first model counts only with the internal costs within the objective function; its goal is to minimize the total costs (TC):

$$min\ TC = 87{,}493x + 497{,}342y$$

where:

x number of standard containers

y number of underground containers.

The values 87,493 and 497,342 are recalled equivalent annual costs of the standard and the underground containers, respectively. Therefore, when the number of containers from each type is calculated, the total costs are expressed at their minimum level.

As was mentioned, an important is represented by the constraints which serve as an input for calculation of the *x* and *y* values. In this model, the constraints consider periodicity of collection, volume of the containers, and number of containers necessary to cover the area based on the number of citizens and the type of the build-up area.

The first constraint is:

$$5{,}923x + 14{,}400y \geq 3{,}554{,}000$$

Right side of the equation is the total volume of waste separated in Prague 3 in year 2009, unfortunatelly, the source and a more up-to-date value is not available. But this value was used as a basis for computation the coefficients on the left. As the x and y variables represent the number of containers, either the standard ones or the underground ones; and the value on the left is the total waste separated per year, the aim was to obtain the capacity of one container in its yearly operations. In other words, how much waste is collected via one piece of standard/underground container per year having the regular collection periods? The computation proceeded:
3,554,000 kg/12 month = 296,167 kg/month

The number of containers that were used to collect this waste – the standard containers:
150 paper containers – collected 12x a month
150 glass containers – collected 8x a month
160 plastics containers – collected 12x a month
120 cardboard containers – collected 4x a month.

Therefore:
296,167 / (150x12 + 150x8 + 160x12 + 120x4) = 54.84 kg/collection/container.

The 54.84 number represents the average amount of waste collected via one standard container. As long as we know, that the underground container has a larger volume, the average amount of waste that can be collected via the underground container is:
54.84 / 1.1m^3 / 3m^3 = 149.56 kg/collection/container.

If we know, that in the underground container, there is approximatelly 150 kg per one collection, then on a yearly basis there is:
150 kg x 8 collections/month x 12 months = 14,400 kg/collection/year.

With the standard containers, the average amount of waste collected per one container per year is approximatelly:

54.84 kg x 9 collections x 12 months = 5,922.72 kg/standard container/year.

The nine collections are an average number of collections per month obtained as (12+8+12+4)/4 = 9.

The second constraint is:

$$x + y \geq 566$$

Again, the x and y are the numbers of standard and underground containers which should be equal or higher 564. The 564 is the minimum number of containers that need to be based on the number of inhabitants living in different urban areas of Prague 3. As was introduced in the theoretical part of this thesis, there are 530 family houses in Prague 3 with approximatelly 2,120 inhabitants, and the remaining 69,020 inhabitants live in either flat houses or prefabricated blocks of flats. As was said, there are requirements on how many container spots should be built up whithin each urban type. In the family houses area, it should be 200 inhabitants per one spot, so in this case it requires 10.6 container spots and in the densely populated area it should be 500 inhabitants per one spot. That requires 138.04 container spots. In total, there should be at least 149 container spots. If we recall, that there are approximatelly 3.8 containers at one spot, this demands 566 containers to be built in Prague 3.

The third and fourth constraint is:

$$x \geq 0$$
$$y \geq 0.$$

These constraints are also called non-negativity constraints which always need to be included in the linear programming problem because we assume that our variable cannot be negative numbers (Ferguson). So in total, the simplified linear programming model excluding environmental benefits is:

$$min\ TC = 87{,}493x + 497{,}342y$$
$$where{:}\ 5{,}923x + 14{,}400y \geq 3{,}554{,}000$$
$$x + y \geq 566$$
$$x \geq 0$$
$$y \geq 0.$$

This model was processed using the Tool for finite math and linear programming (Simplex tableau tool) with the following result:

Optimal solution: c = 52,498,800; x = 600.034, y = 0.

This can be interpreted, that the total costs when minimized are CZK 52,498,800 using the optimal combination of containers as 600 pieces of the standard containers and 0 pieces of the underground containers.

Here we can assume that mainly due to the high costs the standard containers totally outweighted the usage of the underground ones. For the comparison of how do the environmental benefits influence the result, see the following subchapter.

4.6.2 LP Model Including Environmental Costs and Benefits

In this part, essentially the model is the same as in the previous part, with one change. The environmental benefits are included as obtained in the chapter 5.5.4. the environmental/external benefits are included in the model in a form of negative costs associated with the underground containers. Therefore the amount is subtracted from the total amount of the internal costs per one underground container. In numbers it goes:

Internal costs per one underground container: CZK 497,342
Environmental benefits per one underground container: CZK 35,533.
Internal costs – environmental benefits per one underground container: CZK 459,809.

This amount is included in the model instead of the original value of CZK 497,342. The rest of the model remains the same as:

$$\min TC = 87{,}493x + 459{,}809y$$
$$\text{where: } 5{,}923x + 14{,}400y \geq 3{,}554{,}000$$
$$x + y \geq 566$$
$$x \geq 0$$
$$y \geq 0.$$

Again, when processed by the simplex tableau tool, the result given is:

Optimal solution: c = 52,498,800; x = 600.034, y = 0.

The result is the same as when the environmental benefits were not included. We can conclude that the environmental benefits as estimated using the contingent valuatim method are not high enough to outweigh the costs associated with purchase and operation of the underground containers.

4.7 Qualitative Analysis – Expected Pros and Cons of the Underground Containers Compared with Respondents's Opinion – Questionnaire Survey Results

In first section of the empirical part, characteristics of both types of containers were introduced together with their theoretical pros and cons. Since the reality might differ from the assumed functioning, part of the questionnaire survey was focused on respondents' perception of individual characteristics in every-day life. This part of the diploma thesis analyses respondents' opinions on issues related to waste sorting. The questions asked are shown as a supplement of this thesis, see Picture 15 (the translation of the survey was done for purpose of this thesis; originally the survey was carried out in Czech language). The results of the questionnaire survey help to understand how do the people approach waste sorting, what are they oppinions on the new type of containers – what could be improved and what they like about them. In the following paragraphs, relevant findings are introduced.

Out of the 74 asked respondents, 6 of them stated that they do not sort any commodity of the municipal waste. These respondent's answers are handled separately in terms of the reasons for not sorting waste. Within the other questions, if answers are provided and relevant, these are processed together with other respondents' answers.

A) As a reason for not sorting waste, two of the respondents said that they do not trust the system of municipal waste recycling. They believe that everything is put on one big dump, anyway. Two of them stated, that they have the sorting spots away from their home and as a distance they are willing to go to the spot, one of them selected the option 10 – 50 m, the second one 50 – 100 m. Both these distances are shorter than the average walking distance to the waste sorting spots. The last two respondents who do not sort the waste stated the reason laziness and forgetting. The 4 other respondents stated as the maximum distance from their front door to the sorting spot also the 10 – 50 m, the last one even up to 10 m. So even though their main reason for not sorting waste was not the distance, with their attitude the current placement of the sorting spots is not encouraging them to start sorting.

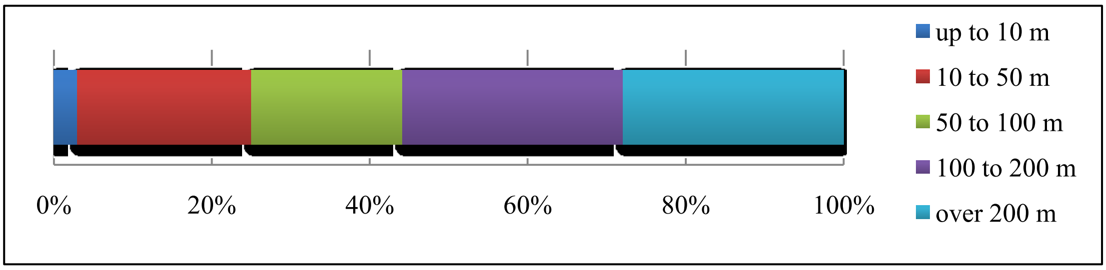
B) Another question was focused on the way people sort the waste. There were two predefined answeres offered and also there was a space for respondents to speicfy their own way they handle the waste and its separation. One of the answers was: “I put everything into one bin, I sorte the waste at the containers.”; the second one was **“**I separate the waste already at home, I have separate bins for individual commodities.”. Together, 68 respondents answered this question, which is logical due to the fact that 6 of them stated they do not sort the waste at all. Adding these two numbers leads us to the original sample size of 74 respondents. Out of the 68 interviewees, 66 used the predefined answers in a ratio 3:63, hence 63 respondents have separate bins/bags/boxes for individual waste commodities, when they go to the separation spot, and they directly throw the whole bag to the container. Only 3 people stated that they put everything into one bin and then they separate the waste at the container spot. the other way presented was that plastics, glass and cardboards are put into one bin at home, paper separately. Thus, paper is thrown away directly in one bag, the three remaining commodities are separated at the container spot. So in fact it is a combination of the proposed ways. The last respondent’s answer was that paper and plastics are put into one bin at home, however it is presorted before going to the containers. Also, this is a combination which at the time of waste collection saves place at home due to only one bin, but when going to the container spot, the commodities are already sorted and disposed in separate bags for individual commodities. Hence this system is more similar to the most frequently used one where presorted bags are already thrown away at the spot.

The reason that led to asking this question was the premise, that the drop-in hole of the underground containers is much smaller than the hole with the standard type of containers. Finding out which way people prefer with waste sorting might help the policy makers to decide whether the size of the lid/hole could be important and convenient for people regarding their home waste sorting method. What they need to find at the sorting spot when they arrive at the container – whether a small drop-in hole is not a problem because most people sort the waste at the container, anyway; or, whether bigger drop-in hole would be more user-friendly as people do not need to bother with being able to put the bag inside the container, even if it is maybe a little bigger in size. The answers help to understand, that 94 % of respondents arrive at the container spot with a bag that they want to directly throw inside. Hence it could be concluded that the bigger the drop-in hole, especially when it comes to paper container, the bigger for the users. As the underground containers have a small chute with hole in it, they might be found less convenient and user-friendly regarding waste sorting.

C) It was already analyzed with those who do not sort the waste, what distance are they willing to go to the containers for waste sorring. It was taken from the point of view, whether the distance might be possibly a barrier for them against waste sorting. Answers of these respondents will not be taken into account in this part which is devoted to those who do sort waste, thus 68 respondents. They answered the question "What maximum distance are you willing to go to the separate waste containers?". This question was close-ended with possible answers: up to 10 m, 10 – 50 m, 50 – 100 m, 100 – 200 m and over 200 m.

Only 2 respondents, 3 %, replied that they are willing to go maximum 10 meters to sort their waste. Considering that these people stated that they sort waste, the probably have the sorting spots very close to their home. Other 15 people, 22 %, stated that they are willing to go between 10 do 50 meters to the sorting spots. 19 % of respondents stated that they are willing to reach between 50 to 100 meters. Hence, alltogether 44 % of respondents' anwers were within the lower part of the scale with the maximum distance of 100 meters for some of them. The higher distance of 100 up to 200 meters was chosen by 19 respondents, it equals 28 % of all people who stated that they sort waste. The last option corresponding to the willingness to go over 200 meters was chosen by other 28 % of respondents. It leaves us alltogether with 56 %. From this it can be concluded, that people do not necessarily have to have the container spots in front of their houses, they are also willing to carry the presorted trash to dispose it. On the scale presented, respondents' answers were spread almost equally with tendency to the right, in other words towards the larger distance. For illustration see Graph 7.

Graph 7 Number of respondents grouped according to their willingness to travel to waste sorting spots, the share on the total numbe of respondents who sort waste



Source: own graph

D) The main part of the questionnaire survey was based on the inputs gained during data analysis. Seven criteria were formulated and evaluated within two likert-scale closed questionns. The criteria were the same, however the questions differed. The first was: "How important for you are the following criteria connected with waste sorting?", the second was: "With the following criteria choose, which type of container you consider as more appropriate for waste sorting.". These two questions were not consequent as in between them there were other questions more related to peoples' knowledge about and experience with the underground containers. However, since the outcomes of these two evaluations are closely related, their outcomes are presented together. Aim of asking such questions was to find out the relation between what people consider important and which type of container they find more suitable with respect to that criteria. This outcome could help to identify, whether the underground containers are more appropriate for waste sorting for peoples' point of view or not.

The seven criteria chosen were: Aesthetics, Easy and fast usage, Safe usage, Vandalism resistance, Size of the drop-in hole, Sufficient capacity of the container and Costs for the municipality. Within the first question, respondents were supposed to say, whether they find the criterion important, quite important, quite unimportant or unimportant. With the second question, they should evaluate, which type of container they find more convenient for waste sorting with respect to the individual criteria. This time respondents were offered a five-point scale with the indifference point in the middle where they do not see any difference between the discussed containers. On one side there is the strong preference of underground containers and on the other a strong preference of the standard containers. In this part, answers of all 74 respondents are considered and evaluated. The summary of the discussed results is in the following Table 1 and Table 2.

Supplementary materials Table 8 and Table 9 with the total number of points awarded are available in the appendix.

With the *Aesthetics* criteria, for 9 people it is important, for 28 quite important, for 21 it is quite unimportant and for 16 respondents the aesthetic part of waste sorting is totally unimportant. This criterion was considered because the aesthetic improvement accompanied with the underground containers was one of the main reasons for their implementation. As we can see, it is so called fifty-fifty in terms of how important aesthetics within waste sorting is. Looking at the result with people's preference in terms of aesthetics and container types, 42 respondents chose the underground containers as more convenient in terms of aesthetics, 13 respondents would rather choose the underground containers, 9 respondents do not see any difference between these two types regarding the aesthetics and 5 people would rather preferr the standard containers, the last 5 respondents choose the standard containers.

Table 1 Count of respondents' answers to question No. 5 in the survey:
How important for you are the following criteria connected with waste sorting?

	Count of respondents' answers Question No. 5			
	important	quite important	quite unimportant	unimportant
Aesthetics	9	28	21	16
Easy and fast usage	42	24	6	2
Safe usage	35	27	9	3
Vandalism resistance	26	30	11	7
Size of the drop-in hole	36	32	4	2
Sufficient capacity	52	18	2	2
Costs for the municipality	11	17	28	18

Source: own computation

With respect to the second criterion, the *Easy and fast usage*, for 42 people it is important to dispose the waste fast and easily. For 24 people it is quite important, for 6 people it is quite unimportant and 2 respondents do not care whether the container is easy and fast to use. Looking at how people see this criteria fulfilled by container type, 6 of them choose the underground containers, 6 would rather choose the underground containers, 38 people do not see any difference, 16 people would rather prefer the standard containers and 8 people would definitely choose them. From the big number of people who do not see any difference between the two container types it could be said, that both types are able to ensure this requirement, the standard containers more.

Regarding the Safe usage criterion, *Safe usage*, most respondents found it important – 35, or quite important 27. Only 9 found the safety quite unimportant and 3 do not see this as an issue with waste sorting. Looking at how the standard and underground containers meet respondents' demand for safe technology, 11 respondents see the underground containers as safe, and 9 respondents have quite the same opinion. On the other hand, 9 respondents would rather have the standard containers and 6 respondents are sure with the standard containers. However the remaining number of 39 respondents who do not see any difference with respect to the safety is relatively high as it was with the previous criterion. Hence even if the safe usage critorion was one of the most important in the final summary, it seems that both types of containers can ensure this.

26 respondents stated that *vandalism resistance* feature of the containers is important for them, 30 said it is quite important. For 11 respondents it is quite unimportant and 7 do not care about this fact. With this criterion, the indifference level is low, only 10 people see both types of containers equally strong when being vandal-resistant, the majority sees the underground containers as the most appropriate – 35 respondents, and 27 respondents see them as rather appropriate. Only 1 respondent sees rather the standard containers as more vandal-resistant and 1 repondent is directly for the standard containers.

Size of the drop-in hole with the container seems to be very important for people, as 36 respondents stated the full importance and 32 said it is quite important. The remaining respondents split their answers as 4 four quite unimportant and 2 unimportant. Here the indifference between the two containers does not reach over 50 % of respondents, still it is quite a high number, 29 people. On the other hand, only 2 respondents would choose the underground containers, and other 2 would rather choose them with respect to the size of the drop-in hole. The remaining 19 respondents are rather choosing the standard containers and 22 are sure with them.

Table 2 Count of respondents' answers to question No. 9 in the survey:
With the following criteria choose, which type of container you consider as more appropriate for waste sorting.

	Count of respondents' answers Question No. 9					
	Underground container	Rather underground container	Indifferent	Rather standard containers	Standard containers	count of answers excl. Indifferent
Aesthetics	42	13	9	5	5	65
Easy and fast usage	6	6	38	16	8	36
Safe usage	11	9	39	9	6	35
Vandalism resistance	35	27	10	1	1	64
Size of the drop-in hole	2	2	29	19	22	45
Sufficient capacity	16	18	30	5	5	44
Costs for the municipality	2	1	25	21	25	49

Source: own computation

The *sufficient capacity* reached the most points in terms of its importance, 52 respondents chose it. Other 18 respondents stated it is quite important. The remaining 4 respondents split their answers equally between options quite unimportant and unimportant. Again the indifference level is at 40 % where 30 respondents do not see any difference in how sufficiently big the containers are. This can be explained by their bad experience of overfilled containers. However 16 and 18 respondents would choose/rather choose the underground containers with respect to the capacity. Equally 5 respondents in each remaining category would more or less strongly vote for the standard containers.

And last, the *costs for the municipality* issue was included in the criteria list to find out, how people think about this issue. 11 people see this as important, 17 as quite important, 28 as quite unimportant and 18 as totally unimportant. As the votes were relatively balanced with respect to importance, with the perception about price it is quite different. 2 respondents feel like underground containers are more convenient in terms of price, 1 respondent thinks it less definitely. On the other hand 21 people see the standard containers as rather to be chosen in terms of costs and 25 people are sure about that. 25 people see none of the container types to be better for waste sorting in terms of costs.

In order to compare, sort the criteria and create the graph, the individual answeres were given points. With the first question, when a respondent chose the "important" option, it was counted as 3 points. The quite important answers were given 2 points, quite unimportant were given just one point as it was assumed that people still might feel at least a little importance over the criteria, and unimportant were given zero points. In the second question, the individual criteria were evaluated on the scale from 4 points for the underground container, 3 points for rather the underground containers, 2 points for rather the standard containers and 1 point for standard container. Zero points were given the answers of indifferent respondents. Therefore the points obtained had to be recalculated for an average value within the second question as long as the zero values and their count might not be interpreted directly. Thus a scale from 1 to 4 was formed where the criteria declining to number one were rather fulfilled by the standard type of container and the criteria which obtained the average value reaching the higher numbers were rather fulfilled by the underground containers.

All these data gathered were put into Table 3 where we can read following information. Firstly, it tells us how important and unimportant the individual criteria are based on respondents' opinion. The criteria are ranked according to their importance and the values obtained for that are shown in the second column of the table. In the very last column, a color scale is presented which is used for color distinction of values in the fourth column. The color and the value show us which type of the container, standard or underground one is considered to be more appropriate for waste sorting with respect to individual criteria. The numbers are reaching from 1 to 4. Based on the numerical evaluation, the container types are seen convenient according to following scale:

1 – 1.75	standard container
1.75 – 2.5	rather standard container
2.5 – 3.25	rather underground container
3.25 – 4	underground container

The colors support the distinction to make it more obvious at first sight.

Table 3 The relation between the importance of individual criteria connected to waste sorting from respondents' point of view and which type of container fulfills it

Importance of criteria		Criteria	Fulfillment by container type	
least important	95	Costs for the municipality	1,59	underground container
	104	Aesthetics	3,42	
	149	Vandalism resistance	3,50	
	168	Safe usage	2,71	
	176	Size of the drop-in hole	1,64	
	180	Easy and fast usage	2,28	
most important	194	Sufficient capacity	3,02	standard container

Source: own computation

Hence, as we can see, the criteria of *Aesthetics* and *Vandalism resistance* are better handled by the underground containers, however, these are the second and third least important based on users' opinion. The least important criterion is the *Costs for the municipality* which is fulfilled the best by standard containers. From this point of view the replacement of the standard containers for the much more costly underground containers is acceptable from the respondents' point of view as they do not care about the costs. The *Safe usage* criterion is slightly more fulfilled by the underground containers, however, over half of respondents saw it fulfilled by both container types equally. And its importance is somewhere in the middle in the list. Similar situation is with the *Easy and fast usage* criterion which is slightly more fulfilled by the standard type of container, however, even if this criterion was ranked the second most important for respondents, over 50 % of them did not see any big difference between which type of container serves this purpose the most.

There are two last criteria to be evaluated. The most important one was the *Sufficient capacity* criterion. Based on the answers, the 3.02 point gained reflects that the underground container type seems to be slightly more appropriate for waste sorting with respect to this requirement. Here it seems that what people want – what is important for them, and what is being implemented – the underground containers, is in a good match.

The last criterion is the *Size of the drop-in hole*. It was ranked as the third most important right behind the Easy and fast usage issue. However, looking at the number of points gained on average, the 1.64 recognizes the standard type of container as being the most suitable with respect to Size of the drop-in hole.

From the survey it seems, that some criteria which were propagated as the reasons for implementation of underground containers are recognized by the respondents, however these are not seen as important (e.g. Aesthetics and Vandalism resistance). The only criterion which is important and also fulfilled by the new type is the Sufficient capacity. Unlikely, the Size of the drop-in hole is very important and at the same time provided by the standard containers. The implementation of the underground containers could be based on this result seen just as partly in line with people's requirements for waste sorting.

E) The respondents were also given the opportunity to express verbally how they evaluate the underground containers, what is the difference, if any, compared to the standard ones.

Within question No. 8 there were 5 sentences started with different level of satisfaction and the respondents were supposed to finish them. The five sentences started as: I am amazed, because …; I am satisfied, they are better than the standard ones because…; I do not see any difference, becaues…; They are worse than the standard containers, because…; I separate waste, but I avoid the underground containers, because…

Out of the responses collected, 10 people stated that they are amazed with specification such as that there is no mess around them, they are more aesthetical, they do not stink and are not robbed. However, even some respondents who were amazed recognized some disadvantages such as big cardboard boxes will not fit in, they have small drop-in holes. For those who are satisfied, which are 16 respondents, the advantages are that the underground containers are less space demanding, there is no trash around them, they are perceived as more aesthetic as they look better, also the increased effectiveness was mentioned. Again, one respondent despite his/her satisfaction stated that the drop-in holes should be bigger. 18 respondents stated that they do not see any difference between these two types of containers, mainly because they do not have much experience with them. Other 12 respondents stated that the underground containers are worse. Following reasons were presented: bigger pieces of trash cannot be thrown inside, then they mess about next to the containers; they have a small drop-in hole; each piece needs to be thoroughly processed; they are right above the ground; these are much more expensive and are not visible, people will not notice them; they have a small drop-in hole and are hardly accessible: low right above the ground, snow…; they are not mobile.

Some other respondents did not choose any predefined variant, however they stated directly their opinion such as: the drop-in holes for cardboard and paper are too small, otherwise it is OK; the underground containers are technically half-backed; they have bigger capacity, there is less mess around them, however they are hardly visible; it is an unnecessarily expensive solution, sometimes these are also built on credit, which should not happen. From the answers it is obvious that people recognize most often the small drop-in hole as an issue together with remarks on technical shortcomings, bad visibility and high costs. On the other hand they like the increased aesthetics.

4.8 Observation Design, Hypotheses and Results

Another important part of the diploma thesis was devoted to the observation of the underground containers within the area of Prague 3. This method was included because one of the proposed improvments that should happen with introduction of the underground containers is the increased aesthetics. To refer to the real situation regarding the aesthetics, the observation was found to be the most suitable method. Some of its outcomes were already presented during the previous chapters to represent individual issues related to the underground containers. However, all the data collected are also analyzed in this part.

At the time of observation 19 underground container spots were build up and in use within Prague 3, for illustration of their placement see Picture 13. All these spots were visited 3 times, namely on 23rd September, 6th October and 19th October 2012. These days were selected with respect to the collection days which should be Monday and Thursday within most of these spots. Therefore, the selected days are Sunday, Saturday and Friday. The observed phenomenon was the level of pollution at the underground container spots. On all spots a photodocumentation was taken and the results were evaluated from the desk. To measure the level of pollution objectively, the following scale was constructed and used:

1	clean, no trash around the containers
1.5	some trash around the containers
2	trash around containers, not clean at first sight
2.5	at least one part of container spot very messy, others moderatelly polluted
3	polluted with lots of trash around all the containers.

The photodocumentation was evaluated according to the presented scale with respect to individual spots and days. The given marks were inscribed into a Table 7. The resultant data were processed in order to answer the two following hypotheses.

The first hypothesis is that the level of pollution is not dependant on the collection day. The first hypothesis was based on the argument presented in favour of the underground containers. It was said, that the bigger volume of the underground containers makes it possible to collect the waste less frequently and thus lower the costs. Through the observation it should be revealed whether on most places the level of pollution/cleanlinness is the same on all the observed days, or whether it changes.

To verify the first hypothesis, the development of the level of pollution within the individual underground spots would have to be the same so that there is no tendency for the situation to get worse or better between the two collection dates. The possible deterioration could be caused by insufficient capacity of the container spots/not enough high frequency of waste collection. In Table 7 we can observe, that at 9 out of 19 spots (47 %), the surrounding of the containers got worse from Friday to Sunday, even though the observation dates were not three days in a row. On 8 out of 19 (42 %) places the aesthetics state was the same and on the last 2 places (11 %) even the improvement was observed. Since on only 8 places the situation was the same, the hypothesis is is rejected. Moreover a tendency for decreased aesthetics was observed as the next collection date was approaching.

The second hypothesis suggests that the underground container spots placed within the historical zone area of Prague 3 are less polluted. Another argument in favour of the implementation of the underground containers was that they help to improve the aesthetics, namely in the historical parts of cities. Therefore the observation and its results should help to identify, what is the pollution level at the spots placed within the historical zone of Prague 3.

To present the results of the observation, the already presented map of underground containers was arranged to distinguish the different levels of pollution by colours. On Picture 14 we can see the historical zone to be located in the Western part of the Prague 3 area. It is delimited by the blue line. Within this zone, at the time of observation, 13 underground container spots were present. To determine the level of pollution, an average value was computed from all the three measurements. The data are presented in Table 7 where the spots in question are marked with a star by the average value. Out of the 13 spots, 7 (54 %) were on average not polluted or just a little within the three observation measures. 5 out of the 13 spots (38 %) were found polluted, some trash was outside the containers, sometimes one container out of the three was completely full, but the other were ready to use. 1 spot (8 %) placed in the historical zone of Prague 3 reached the worst valued of all spots, two times it was given mark 3, once it obtained mark 2. Mostly all container chutes were surrounded by trash. Since one of the main goals of the underground containers were to improve the aesthetics and move the trash underground, its proper functioning can be doubted since within three observations, 46 % of spots were on average found more or less polluted.

It was shown that on many places there is trash lying around the underground containers. The question is what caused the pollution. Whether these were pieces of trash which was impossible to throw in the container due to the small drop-in hole, or whether the container was already full and no other trash would fit in (let's assume these two reasons as the major ones). Based on the observation, in 19 cases the pieces of trash lying around the container were too big to fit in the drop-in hole without any previous adjustment. Often these were the cardboard boxes which would have to be cut in many small pieces to fit in. on the other side in 5 cases the containers were found too full to take in any other bag with trash or a plastic bottle.

The author is aware of the fact, that only a small number of measurements were taken in order to consider the results as predicative and representative. Hence, further research in this field would be appropriate to incorporate the demographic issues and also the availability of other waste sorting spots in the surrounding of the observed underground container spots.

4.9 Conclusions and Recommendations

To introduce a waste management system that is succesfull and efficient is requires a very good knowledge of the given area. As Kotoulová (2008, p. 14) says, "*each type of separated waste collection has its pros and cons, and it is necessary to search for a locally feasible solution which is technically, economically and socially acceptable*". As a result of the practical part of this diploma thesis, conclusions are made with recommendations given, when appropriate and possible. Some of the recommendations are based on approaches and systems already used. Because municipal waste saparation is an issue handled by many cities and countries, when looking for a solution for Prague, it would be unwise not to look at other ways of waste separation management.

A) One of the findings was that the implementation of the underground containers is very costly opposed to that of the standard containers, also people's willingness to contribute is not sufficient to outweigh the costs. One possible option is to stop building the underground containers and come with a cheaper option. The new system might be based on the standard type of containers, but their placement could be changed so that it is more stable, to lower the possibility of vandalism; and closer to people so that the probability of more people actually participating on waste sorting increases. The examples for improvement follow.

At Archipelago of the Azores, which politically belongs to the Portugal, among others the standard types of containers are used for waste separation. Thus in terms of size and place requirements, the containers are the same. However, due to the weather conditions and also terrain, which is often hilly, the containers need to be prevented from movement. In order to ensure this, a simple paling made from metal is build for each container separately. When collecting the waste, the paling is simply lifted up which releases the container for manipulation, it can be moved to the collection truck, be emptied and then returned to the paling. For illustration of this type of container placement see picture Picture 16. This type of fastening is simple to be build-up and fast to be manipulated with. What is not apparent from the picture is wheather the paling can be locked, so that only the servicemen of waste collection trucks can open it, or it is unsecured. If it was possible to make the paling lockable, it would also help to prevent from intentional movement of the containers by vandals. Also as the palings are fixed, containers are returned to the same place and the overall impression is positive as they are in a row, aligned. The second type of container placement is used on Azores islands, this time on Faial Island For illustration see Picture 4 on the following page.

Individual wooden sheds are built for each of the containers which make them in general hidden altogether; people can only reach the opening lid and throw in the waste. This type of container fixation is definitely more expensive than the previous one; however, for historical parts of city it would be applicable as the aesthetics is improved opposed to the solitary containers. This type has a similar vision as the underground containers, to hide the trash and containers as much as possible. These two types of fixation would improve the vandalism issue, also the aesthetics and prevent from unintentional moves of the containers due to the weather conditions.

Picture 4 Wooden sheds for standard containers; Faial Island, Azores

Source: own photograph, taken 8/2012

B) If it was decided by the municipal part representatives to keep the standard containers, another issue could be solved more easily. The distance people have to cover in order to separate waste. As was calculated, the number of spots would decrease with implementation of the underground containers. This is outweighted by bigger capacity, however, if people are not willing to go that far to a waste sorting spot, the increased capacity does not help to sort more waste. It is seen as crucial to bring the sorting spots as close to people as possible. Keeping in mind the aesthetics issue, one can have a look at other cities' and municipal parts' solution. Based on the legislation, it is set that in municipal historical zone areas, the containers cannot be placed directly on streets in order not to disturb the historical surrounding. In near-by Prague 2 and Prague 1 districts, the containers are placed directly in the halls right behind the entrance to the house or block of flats. As the type of houses enables this placement, the containers are not visible on the street and are locked behind the front door which makes them also available only to the inhabitants of the house. This solution could be also applied to the historical zone area of Prague 3. It is apparent without any further analysis that this method is more demanding in terms of time for waste collection, organization and labour. Further calculations are necessary to prove, whether this sollution would bring the desired outcome of improving the aesthetics and bringing the waste separation spots closer to people.

C) One of the biggest drawbacks of the new type of containers was found to be the small drop-in hole. Despite the security and efficiency arguments, people find it hard to use. Hence, some respondents also stated that due to this novelty they separate less waste. As with the previous issues, one option would be to keep the standard containers whichs lid enables people to throw in even bigger pieces of cardboard. However, there is also another option. Another type of underground container is manufactured. In general it is called the SEMI type, as a bigger part of it is located above the ground, there is not only the chute. Hence, they occupy bigger place, but the drop-in hole is bigger. For illustration of this type of container see Picture 17. As this type of container has its bigger part placed above the ground, there is also a bigger place for the lid. There are more options to choose from when it comes to the shape and size of the lid, so one can select the best one for the area in question. Also the volume of these containers is bigger, even bigger than with the currently implemented underground containers. The SEMI underground container has volume of 5 m^3. As it's approximately one third is placed above the ground, the space requirement is higher. Hence this type is more suitable for block of flats urban area and area with parks rather than crowded historical city centres.

D) The Prague 3 area is a diverse city district in terms of the urbanism type. Hence, in some part of the area, preservationists' requirements need to be taken into account and in the other part there are more parks and family houses which need to be taken care of differently. Considering all the proposed solutions above, a possible optimum waste management system for Prague 3 could be designed.

Basically the area of Prague 3 could be divided into two parts – the historical zone part in the West and the rest of the area in the East. Within the historical zone area, and in areas with similar types of urban development, the containers for waste separation would be placed within individual houses. On public places such as Jiřího z Poděbrad place, Mahlerovy sady park under the Žižkov Tower, park at Husinecká street in front of the Victoria Žižkov Football Club Stadium, Havlíčkovo place and park in front of the High School of Economics in Prague the underground containers might be introduced. Within the Rajská Zahrada Park, SEMI underground type of container might be applicable.

Within the remaining area of Prague 3, the combination of fastened standard containers and SEMI underground containers would be implemented in places where the blocks of flats or family houses have bigger distances among themselves. The standard containers might be either fixed by the padling or by the shed to improve the aesthetics but to prevent from financially demanding construction.

Apparently, as more types of waste management methods would be introduced, the more demanding would the system be regarding planning of waste collection. Also the efficiency might be lowered due to lower utilization of means of waste collection. However, when the resources are planned well, the economic operationing would be feasible. Still the proposed combination is not that much diverse in type of waste sorting methods. From a broader perspective, other ways of municipal waste recycling could be employed besides drop-off containers such as door-to-door collection and return for refound. However, as Halvorsen (p. 25, 2012) states in his article, the drop-off way of waste disposal is one of the two most effective ones. The second one is door-to-door collection. Robinson (p. 78, 2005) says within his research that respondents referred to the fact that the system of drop-off containers/sites enabled people to sort no matter the day of the week and no matter the day time. Moreover, the drop-off containers are well established in Prague and as Kotoulová (2008) says, it takes from 3 to 5 years to fully implement a change in municipal waste sorting. Therefore, any changes should be considered carefully.

To ensure even bigger compliance of the citizens with separate waste management system, a survey might be proposed asking about what way of waste separation people find the most useful, how important the distance from their home is etc. to include the inhabitants in decision making in general brings better compliance as people feel as a part of the happening. Well, the resources from which the build-up of underground containers is financed come from taxes of these people, and then they should have the right to express their opinion.

When talking about the underground solutions and going further beyond the borders of what is currently feasible in Prague, one example from Sweden is included to illustrate how waste separation system might work. It is an example from one part of Stockholm, the Hammarby Sjostad, a new eco-neighbourhood which was build in a sustainable way. The inhabitants of this part dispose the trash through chutes where the trash travels through pneumatic tubes directly to the trash processor. All the trash disposed throught the tubes is separated into food, which will be composted, paper to be recycled and then garbage ment to be incinerated. Other commodities are separated directly in the houses where there are special rooms for disposal of e.g. old electronic appliances, light bulbs, plastics etc. (Time Magazine, 2009). Such a system is for now just a prototype of a sustainable city, still it is very inspirational. It brings the waste separation as close to people as possible and it uses an ecofriendly way to do that as thanks to the tubes, collection trucks do not need to enter the area for collection of commodities in question.

E) One point to be included here does not emerge directly from the findings. As was explained in previous chapters, the underground containers implemented in Prague 3 are supplied by a German company SSI Schäfer. These containers are manufactured and transported from Germany. However, in the Czech Republic there is also a manufacturer of such a type of containers. It is called REFLEX Zlín, spol. s r. o. This Czech company has its plant near Zlín and it focuses on production of fibreglass laminate products, mainly containers. For example city such as Uničov has implemented underground containers produced by REFLEX Zlín.

Data on the selection procedure of the underground containers supplier are not available and therefore it is not possible to say, whether this company was also an applicant for this tender. And if it was, what was the exact reason for its denial. However, the basic idea behind this information is that supplying products made within the Czech Republic would be at least more efficient in terms of transportation costs whilst from the manufacturing plant in Germany located in Neunkirchen is it over 600 kilometers to Prague, however the distance between Prague and Zlín is 300 kilometers (Google Maps, 2013). Also selection of a Czech manufacturer would support the Czech economics.

F) The last recommendation stemms out of the comparison of waste separation level among individual European states and also by some respondents' attitude towards waste sorting. The level of municipal waste separation in the Czech Republic is still lagging behind other European countries' level, and in this case this is mainly due to the approach of the inhabitants. As also resulted from the questionnaire survey, there is still a group within the population which does not believe that the sorted waste is actually processed in a right way. Some people are sceptical and doubtful, they believe that the waste is mixed with other commodities anyway and that sorting is just a waste of time.

To eliminate this mood and bring more people to waste sorting, education and enlightment is needed to support the habit of waste sorting. Some educational programmes are introduced for schools, there exists a catalogue of possible excursions related to waste management (Envis, 2012) and also there are events devoted to waste separation where not only children can play various games and participate in competitions. However, there are not many initiatives focused on adult population. If children in a family feel the need to separate waste and are thought so at school, it is of no good when their parents at home are against waste separation whether it is due to the lack of information or disbelief in the system.

5 Conclusion

The main aim of this diploma thesis was to evaluate the currently implemented innovative type of underground containers for municipal waste sorting in part of the capital city of the Czech Republic, Prague 3. Previous to that the situation in the Czech Republic and more specifically in Prague 3 was analyzed to understand what are the current methods options for waste sorting, and how should the new type of containers actually contribute to the current system.

It is concluded, that municipal waste sorting is available for citizens of the Czech Republic in almost every village and that there is a focus on increasing the level of waste sorted. In Prague 3, the system ensuring waste sorting is relatively diverse with bring-in sites for bulky and hazardous waste, drop-off containers for plastics, paper, glass and on many places also cardboard packages. Moreover there are mobile collection spots operated several times in a year; disposal of batteries, expired drugs and also the possibility to return the beer bottles is operated via drug stores, supermarkets and schools. Finally, the mixed waste is disposed via containers and dustbins located near houses. However, it was unterstood that a big part of the mixed municipal waste consists of the biodegradable waste components, for which there is literally no organized disposal system. If one wants to dispose this waste, he/she needs to arrange the dustbing on his/her own and pay for it. The main reason why this is not happening is probably low informedness and also the fee. The inhabitants are used to pay for the mixed waste dustbins/containers, however, the other commodities' disposal is not directly charged.

The underground containers should according to a plan from year 2009 replace in most places the currently used "standard" containers for plastics, paper, glass and cardboard packages. Thus they are seen as an innovative solution which should increase the capacity of sorting spots and make the waste sorting more aesthetical. The two container types were compared and evaluated with respect to the costs needed for their implementation operation. It is concluded that by implementing the underground containers, the capacity of containers would increase by 67%. That would enable a less often collection of dustbins. However, the new containers need to be operated by a special truck, so the investment into machinery and thus higher costs are inevitable in the beginning.

As long as less container spots are actually designed to be built within the area of Prague 3, this would prolong the distance people need to go/travel with the trash to the container. Based on other experience of other municipalities' representatives, the distance is often very important for waste sorting and citizens' compliance. Compared to the questionnaire survey results, the non-recyclers stated on average an optimum distance around 50 m, the current average distance is estimated about 106 m (EKO-KOM, 2011b). Prolonging this distance would most likely not help to gain new recyclers.

The main reason why the underground containers were introduced was the improvement of aesthetics. Based on observation, on some places the solution works well, at the same time there are spots which are highly polluted. Big pieces of trash and bags are lying around the containers which are either full, or they are empty, but the bigger pieces will not fit into the small drop-in hole, or as the first person lied a bag next to the container, the others did not bother to have a look whether there is a free space inside.

This can be linked to conclusions about the pros and cons of the underground containers as compared to the standard type. One of the aims of the thesis was to outline which criteria are important for people with regard to waste separation and by which type of container these are better fulfilled. The outcome is that the most important criterion is the sufficient capacity addressed by the underground containers. The second most important criteria was the easy and fast usage which was according to the questionnaire results explained rather by the standard containers. The third most important was the size of the drop-in hole, which was fulfilled by the standard containers as well. The safe usage followed on fourth place fulfilled slightly more by the underground containers; next two criteria were fulfilled by the underground containers as well: the vandalism resistance and the aesthetics, however these criteria were seen as the second and third least important. The very last in terms of the importance for end-users was the costs for the municipality; still it was recognized to be more favourable with the standard containers. To conclude, the mostly propagated criteria, the aesthetics was not really demanded and important for the respondents, rather more practical criteria such as capacity, easy and fast usage and size of the drop-in hole.

This links to the main objective of the thesis which was to find what are the costs and eventually the benefits associated with both types of containers and to assume the optimum number of each container to be implemented keeping the costs at the minimum. Two scenarios were presented in the simplified linear programming model; one did not consider the environmental benefits, the second scenario did. The solution for the second model is that only the standard containers are used in order to minimize the costs. In the second model, the environmental benefits in a form of inhabitants' willingness to pay are included. However, the result is the same. Again solely the standard containers are proposed.

The author tried to give several recommendations based on the results. It was shown, that the more expensive solution does not improve the situation much, so one sugestion is to stop the implementation of the underground containers in order to minimize the costs. At the same time it would be possible to increase the number of spots and thus bring the sorting closer to people. The technical issue with the small drop-in holes could again be addressed by sustaining the standard containers, or by implementing another construction type, such as the SEMI underground containers produced by a Czech company REFLEX Zlín. This would also mean that a Czech supplier and manufacturer would be selected. That migh decrease the transportation costs as well as support Czech economics. Finally it is concluded, that increasing the aesthetics especially in the city centres is very welcome and needed, and however, the main focus should be on the primary function of the containers. Since the level of waste sorting in Prague 3 and in the Czech Republic is still lagging behind other European countries, it is recommended to focus rather on increase of the amount of waste sorted and to improve and support people's attitue towards waste sorting.

6 Resources

6.1 Literature

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7 Lists of Graphs, Tables and Pictures

7.1 List of Graphs

7.2 List of Tables

7.3 List of Pictures

8 Appendices

8.1 Graphs and Tables

Table 4 Computation of the NPV and EAC for the Standard containers

Standard Containers	
Investment Costs per Standard Container	7 000 CZK
total costs of the whole system (ENVIS 2009) (operational, machinery, administration):	
Prague	1 005 284 000 CZK
Prague 3 (5.7 %)	57 301 188 CZK
1st year -costs 60 % of total	34 380 713 CZK
2nd year - costs 60 % of total	34 380 713 CZK
from 3rd year on - costs 100%	57 301 188 CZK
Operational Costs per Standard Container	98 795 CZK

	2009	2010	2011	2012	2013	2014	2015	
Year	1	2	3	4	5	6	7	Total
Ordinary Costs Standard Containers	36 410 713 CZK	36 410 713 CZK	57 301 188 CZK	57 301 188 CZK	57 301 188 CZK	57 301 188 CZK	57 301 188 CZK	
Discount Factor	0,962130542	0,92569518	0,890639605	0,856911566	0,824460789	0,793238906	0,763199378	
Discounted Ordinary Costs	35 031 859 CZK	33 705 221 CZK	51 034 707 CZK	49 102 051 CZK	47 242 583 CZK	45 453 532 CZK	43 732 231 CZK	305 302 184 CZK

Sum of Discount Factor (7 years)	6,016275964
EAC (Equivalent Annual Costs)	50 746 040 CZK
EAC per 1 Standard Container	87 493 CZK

Source: own computation

Table 5 Computation of the NPV and EAC for the Underground containers

Underground Containers	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2028	
Year	1	2	3	4	5	6	7	8	9	10	20	Total
Ordinary Costs	2 347 704 CZK	11 323 579 CZK	35 986 489 CZK	69 646 022 CZK	102 557 564 CZK	135 469 107 CZK	165 367 945 CZK	195 287 529 CZK	225 207 113 CZK	252 124 366 CZK	252 072 498 CZK	
Discount factor	0,962130542	0,92569518	0,890639605	0,856911566	0,824460789	0,793238906	0,763199378	0,734297431	0,706489985	0,679735592	0,462040476	
Discounted Ordinary Costs	2 258 797 CZK	10 482 183 CZK	32 050 992 CZK	59 680 481 CZK	84 554 690 CZK	107 459 366 CZK	126 208 712 CZK	143 399 131 CZK	159 106 570 CZK	171 377 905 CZK	116 467 697 CZK	2 290 759 520 CZK
number of spots built in that year	1	4	11	12	11	11	10	10	10	9	0	
number of containers built in that year	3	12	33	45	44	44	40	40	40	36	0	
number of containers in total	3	15	48	93	137	181	221	261	301	337	337	
machinery costs (assumes higher expenses in beginning of the	1	1	0,8	0,8	0,8	0,8	0,6	0,6	0,6	0,5	0	
Investment per 1 Container plus Build-up Costs	644 254,7 CZK											
Operational, Administration and Machinery Costs/Container/Year = 105 % of Standard Container Operational Costs	103 735 CZK											
Sum of Discount Factor (20 years)	13,66767084											
EAC (Equivalent Annual Costs)	167 604 235 CZK											
EAC per 1 Underground Container	497 342 CZK											

Source: own computation

Table 6 Computation of the NPV and EAB for the Underground Containers

Underground Containers	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2028	
Year	1	2	3	4	5	6	7	8	9	10	20	Total
External Benefits	169 393 CZK	846 967 CZK	2 710 295 CZK	5 251 196 CZK	7 735 633 CZK	10 220 069 CZK	12 478 648 CZK	14 737 227 CZK	16 995 806 CZK	19 028 527 CZK	19 028 527 CZK	
Discount factor	0,962130542	0,92569518	0,890639605	0,856911566	0,824460789	0,793238906	0,763199378	0,734297431	0,706489985	0,679735592	0,462040476	
Discounted EB	162 979 CZK	784 033 CZK	2 413 896 CZK	4 499 810 CZK	6 377 726 CZK	8 106 957 CZK	9 523 697 CZK	10 821 508 CZK	12 007 367 CZK	12 934 367 CZK	8 791 950 CZK	172 876 684 CZK

Total WTP / year	19 028 527 CZK										
EB / 1 container / year	56 464 CZK										
number of containers built in that year	3	12	33	45	44	44	40	40	40	36	0
number of containers in total	3	15	48	93	137	181	221	261	301	337	337

Sum of Discount Factor (20 years)	13,66767084
EAB (Equivalent Annual Benefits)	12 648 584 CZK
EAB per 1 Underground Container	37 533 CZK

Source: own computation

Table 7 Observation data, data on level of pollution around underground container spots

Official ID	Research ID	Location	Friday 19. 10. 2012 Level of pollution	Saturday 6. 10. 2012 Level of pollution	Sunday 23. 9. 2012 Level of pollution	Average level of pollution /container spot	Development of pollution between collection days
0003/ 052	14	Ke Kapslovně u č. 16	1,5	1,5	1,5	**1,50**	=
0003/ 132	19	Pod Lipami u č. 41	1	1,5	1,5	**1,33**	↓
0003/ 150	6	Žižkovo nám. x Křišťanova	2	1	1	**1,33***	↑
0003/ 151	15	Jeseniova u ZŠ proti č. 95	1,5	2	2,5	**2,00**	↓
0003/ 152	1	Nám. Jiřího z Lobkovic u č.7	1	1	1	**1,00***	=
0003/ 153	9	Milešovská x Ondříčkova	1	1	1	**1,00***	=
0003/ 154	17	U Kněžské louky proti č.4	1	1	1	**1,00**	=
0003/ 155	13	Siwiecova x Seifertova u parku	1	1	3	**1,67***	↓
0003/ 156	7	Ondříčkova x Žižkovo nám.	1	1	1,5	**1,17***	↓
0003/ 157	2	Libická x Vinohradská	1,5	1,5	2,5	**1,83***	↓
0003/ 158	10	Fibichova proti č.15	1,5	1,5	1,5	**1,50***	=
0003/ 159	12	Slavíkova x Křížkovského	1	1	2	**1,33***	↓
0003/ 160	3	Lucemburská x Velehradská	1	1	2	**1,33***	↓
0003/ 161	5	Křišťanova x Sudoměřská	1,5	1,5	2	**1,67***	↓
0003/ 162	4	Lucemburská x Sudoměřská	1	1	1	**1,00***	=
0003/ 163	18	Květinková proti č.13	1,5	1	1,5	**1,33**	=
0003/ 164	16	Jeseniova x Hořanská	1,5	1,5	1	**1,33**	↑
0003/ 165	8	Ondříčkova 26/2395	1	1	2,5	**1,50***	↓
0003/ 166	11	Škroupovo nám. č.2/2709	3	2	3	**2,67***	=
		Average level of pollution / day:	**1,34**	**1,26**	**1,74**	**1,45**	

Table 8 Total points awarded for all answers according to the individual criteria in question No. 5

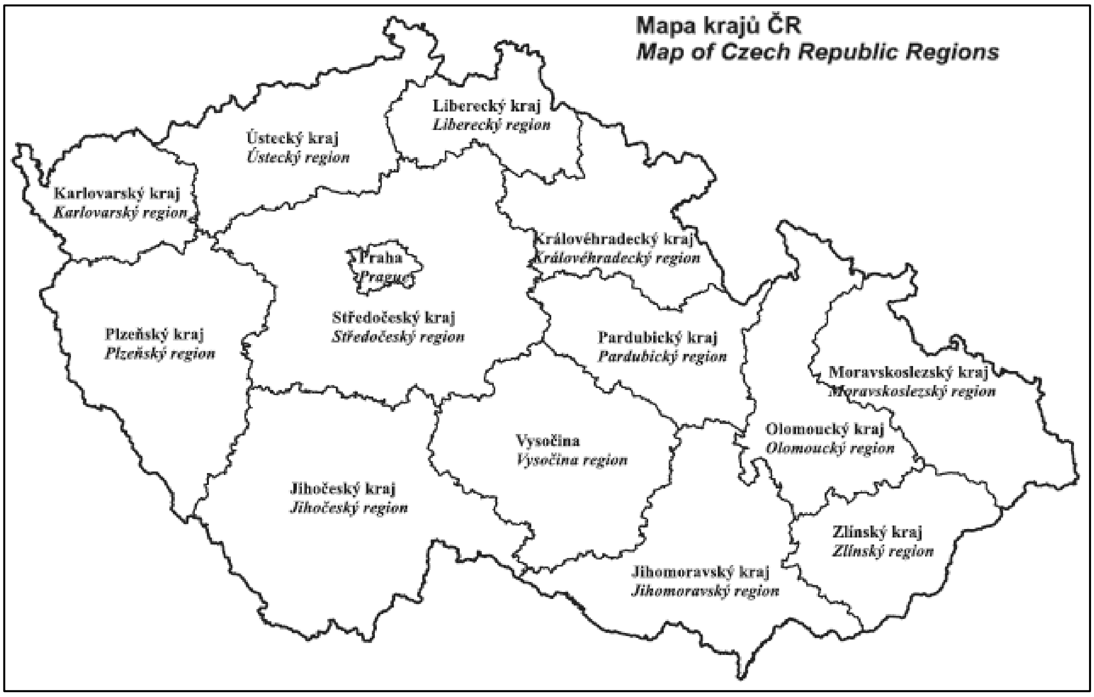
	Total points awarded for answers in question No. 5				
	important	quite important	quite unimportant	unimportant	sum
Aesthetics	27	56	21	0	104
Easy and fast usage	126	48	6	0	180
Safe usage	105	54	9	0	168
Vandalism resistance	78	60	11	0	149
Size of the drop-in hole	108	64	4	0	176
Sufficient capacity	156	36	2	0	194
Costs for the municipality	33	34	28	0	95

Table 9 Total points awarded for all answers according to the individual criteria in question No. 9

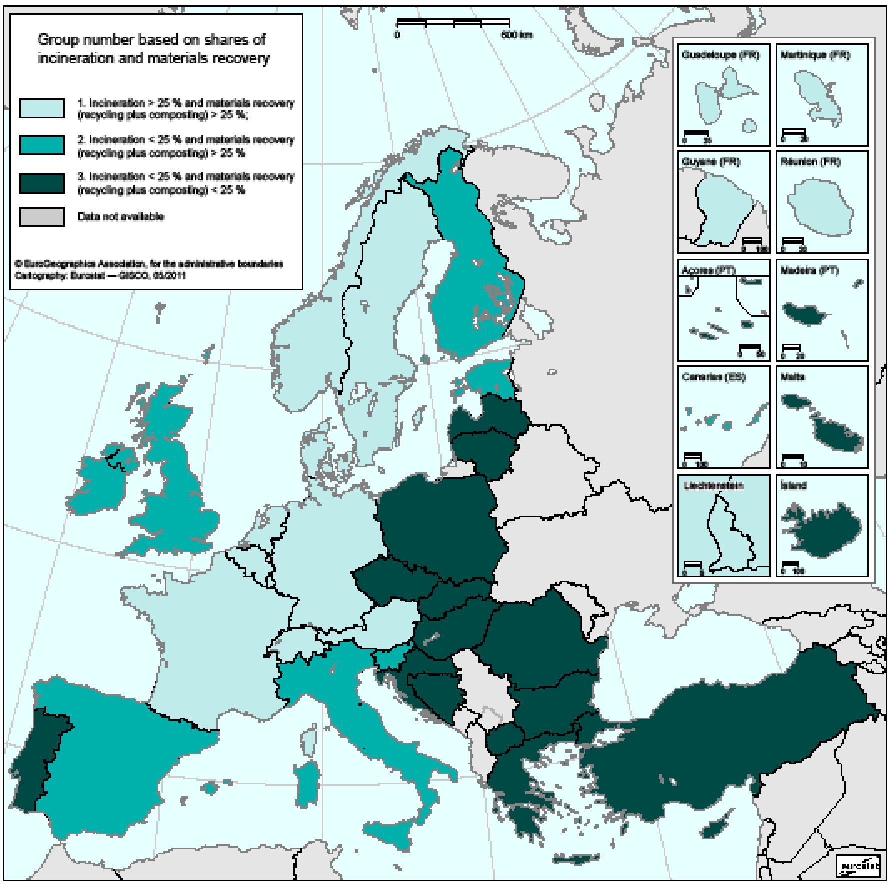
	Total points awarded for answers in question No. 9						
	Underground container	Rather underground container	Indifferent	Rather standard containers	Standard containers	sum	average (sum/count of answers excluding Indifferent - Table 3)
Aesthetics	168	39	0	10	5	222	3,42
Easy and fast usage	24	18	0	32	8	82	2,28
Safe usage	44	27	0	18	6	95	2,71
Vandalism resistance	140	81	0	2	1	224	3,50
Size of the drop-in hole	8	6	0	38	22	74	1,64
Sufficient capacity	64	54	0	10	5	133	3,02
Costs for the municipality	8	3	0	42	25	78	1,59

8.2 Pictures

Picture 5 Map of Regions in the Czech Republic

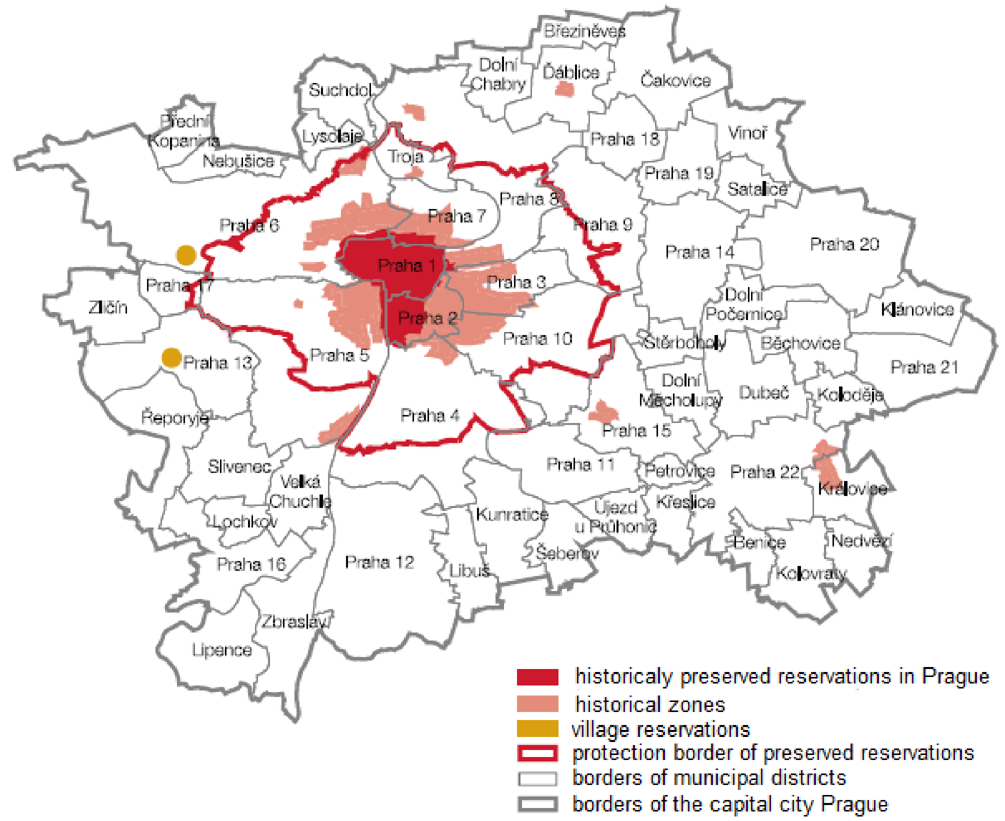


Picture 6 Waste Treatment Strategy by Country Groups, 2009



Source: Eurostat (online data code: env_wasmun)

Picture 7 Historically preserved areas in Prague



Source: URM

Picture 8 A) Preparation for the instalation of underground containers; B) Placement of the underground containers

A)

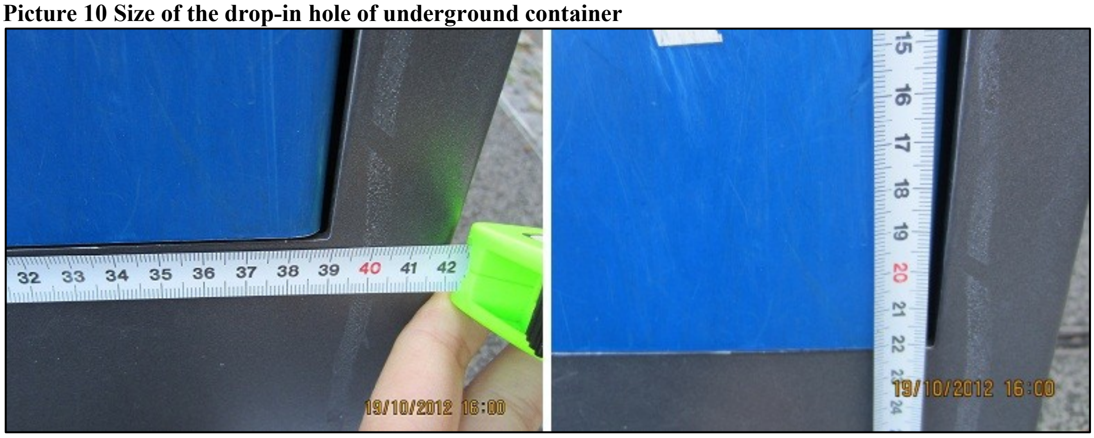
B)

Source: SSI Schäfer

Picture 9 Mess around the containers at underground containers spot in Libická Street, Prague 3

Source: own photograph

Picture 10 Size of the drop-in hole of underground container

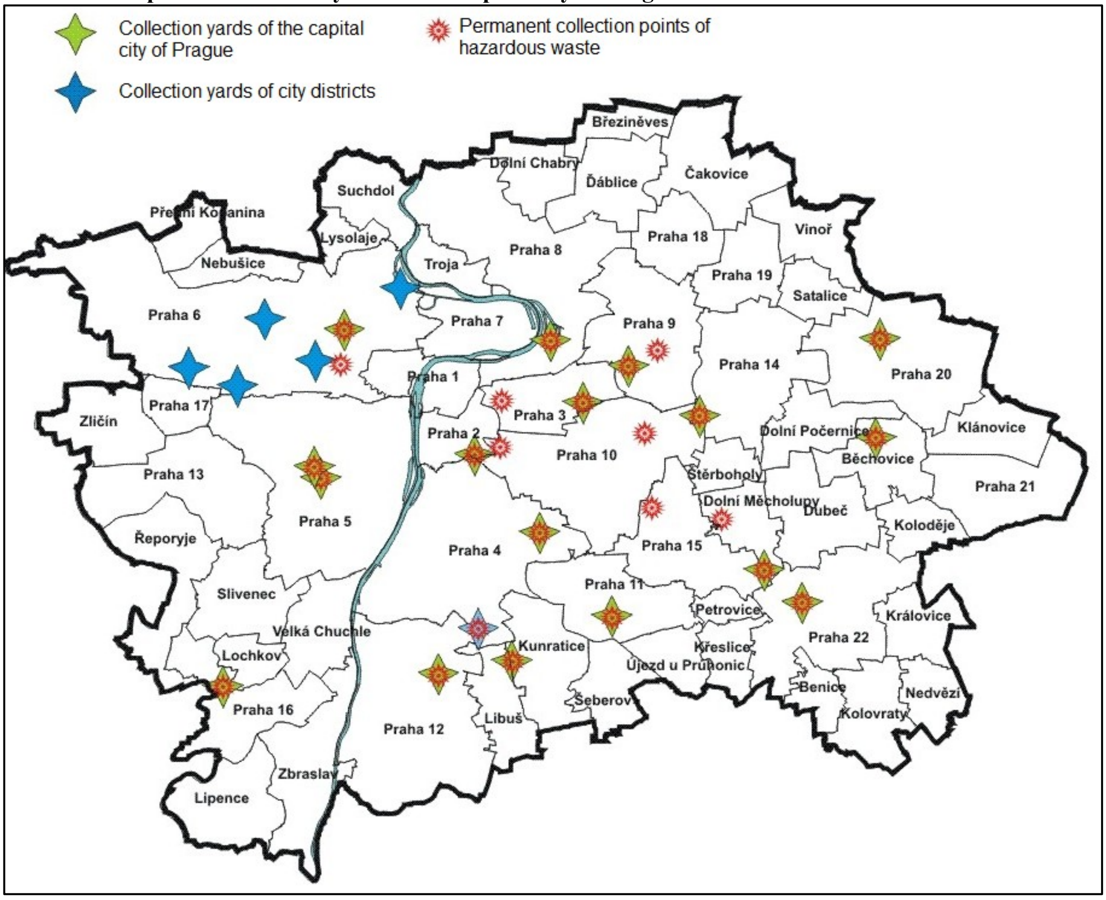


Source:own photograph

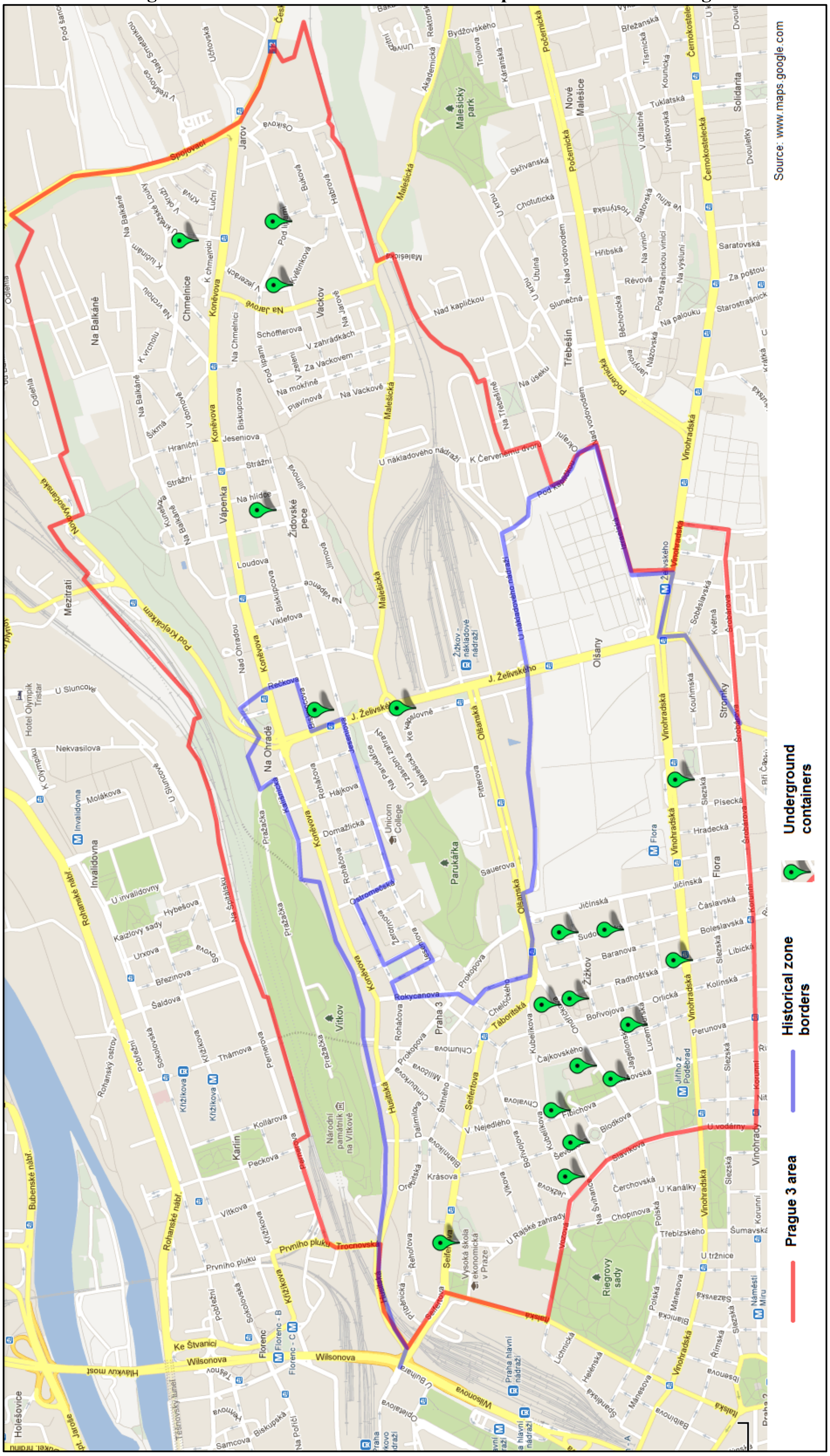
Picture 11 A sheet of glass – impossible to throw in the container through the round drop-in hole

Source: own photograph

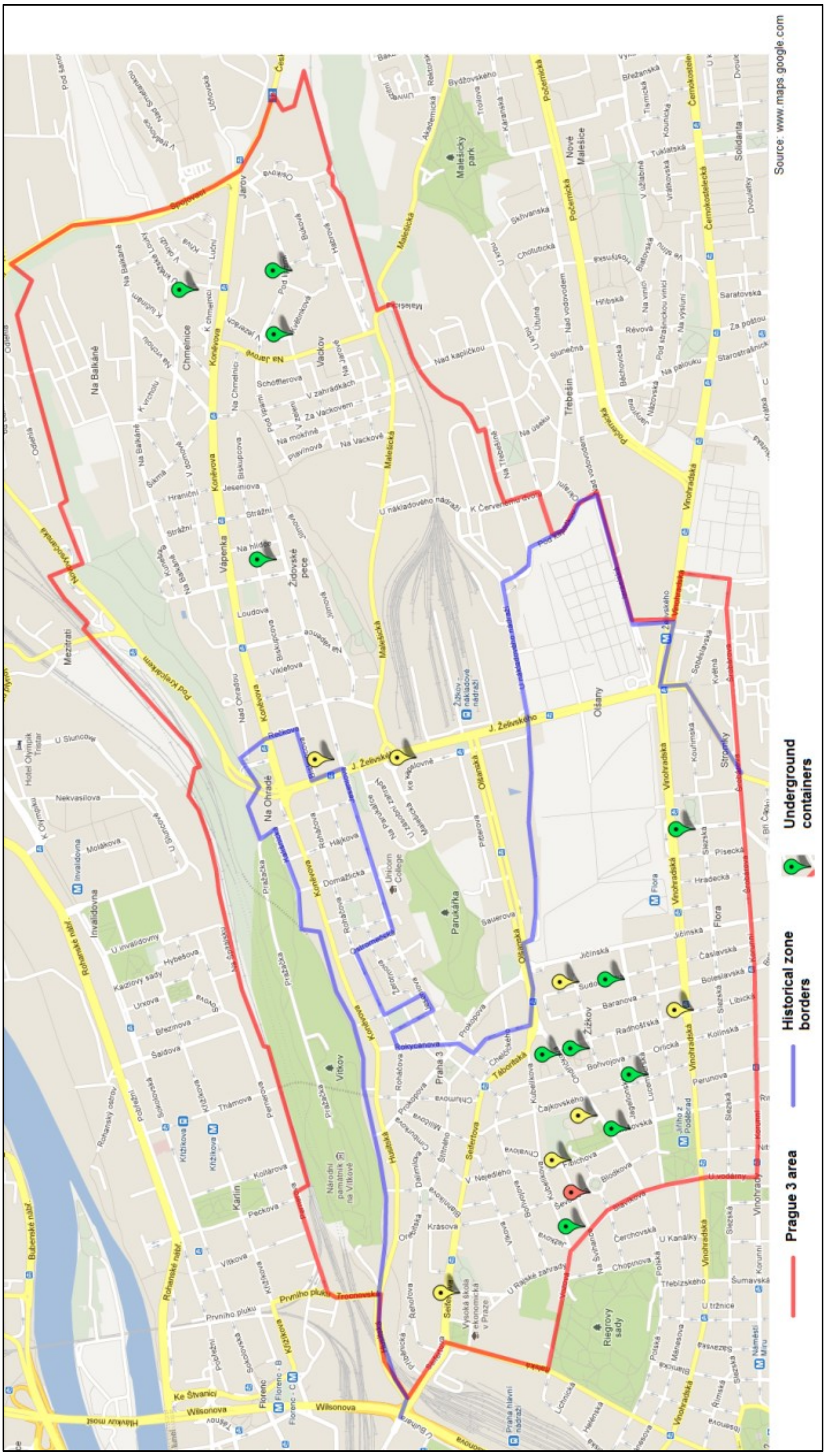
Picture 12 Map of the collection yards in the capital city of Prague



Picture 13 The area of Prague 3 with delimited Historical zone and placement of the underground container spots.



Picture 14 The level of pollution at the underground container spots in Prague 3



Picture 15 Questionnaire survey

Survey – Municipal waste sorting

1) At home I sort:

☐ plastics ☐ paper ☐ glass ☐ beverage cardboards ☐ nothing

If you answered: „nothing“, please answer only questions No. 2, 4, 7, 8, 12 – 16.

2) State the reason for not sorting waste:

☐ containers are too far from my home

☐ I do not think it is necessary.

☐ I do not believe that the systém works, they put it all together, anyway.

☐ I do not want to have multiple dust bins at home, I am fine with just one bin.

☐ another reason:____

3) How do you sort waste?

☐ I put everything into one bing, I sort the waste at the containers.

☐ I separate the waste already at home – I have separate bings for individual commodities.

☐ different way:____

4) What maximum distance are you willing to go to the separate waste containers?

☐ up to 10 m ☐ 10 – 50 m ☐ 50 – 100 m ☐ 100 – 200 m ☐ over 200 m

5) How important are for you the following criteria connected with waste sorting?

	Yes	Rather yes	Rather not	Not
Aesthetics	☐	☐	☐	☐
Easy and fast usage	☐	☐	☐	☐
Safe usage	☐	☐	☐	☐
Vandalism resistance	☐	☐	☐	☐
Size of the drop-in hole	☐	☐	☐	☐
Sufficient capacity of the container	☐	☐	☐	☐
Costs for the municipality	☐	☐	☐	☐

Underground container

Standard container

6) Do you use the „underground containers“?

☐ yes, regularly ☐ yes, sometimes ☐ no ☐ I have never seen them.

7) How do the underground containers affect your way of waste sorting?

☐ I didn't sort the waste untill now, but I have started due to the underground containers.

☐ I started to sort more

☐ Underground containers do not affect my style of waste sorting

☐ I started to sort less

☐ I quit sorting

1 EUR = 25.38 CZK (CNB 16. February 2013)

8) How do you evaluate the underground containers?

- ☐ I am amazed, because ____
- ☐ I am satisfied, they are better than the standard ones, because______________________
- ☐ I do not see any difference, because_______________________________________
- ☐ They are worse than the standard containers, because____________________________
- ☐ I separate waste, but I avoid the underground containers, because__________________

9) With the following criteria choose, which type of container you consider as more appropriate for waste sorting:

	Underground containers	Rather underground c.	The same	Rather standard c.	Standard containers
Aesthetics	☐	☐	☐	☐	☐
Easy and fast usage	☐	☐	☐	☐	☐
Safe usage	☐	☐	☐	☐	☐
Vandalism resistance	☐	☐	☐	☐	☐
Size of the drop-in hole	☐	☐	☐	☐	☐
Sufficient capacity of the container	☐	☐	☐	☐	☐
Costs for the municipality	☐	☐	☐	☐	☐

10) Imagine that you can choose which type of container will stand on the place where you normally sort waste, you would choose:

- ☐ underground container
- ☐ standard container

If you ticked answer: underground container, continue with No. 11. Otherwise skip to question 12.

11) Build-up and operations of the underground containers is very costly. Would you be willing to pay higher fees for waste collection and thus contribute to the build-up and operations of underground containers at place of your home? By how much more would you be willing to pay?

- ☐ No, I do not want to contribute, I'd rather keep the standard containers
- ☐ Yes, maximum by 50 CZK / month
- ☐ Yes, maximum by 100 CZK / month more
- ☐ Yes, maximum by 200 CZK / month more
- ☐ Yes, by more than 200 CZK / month more

12) Gender: ☐ Male ☐ Female

13) Age: _______ years

14) Number of citizens in municipality of your origin:

☐ up to 2 000 inhabitants ☐ 2 – 10 000 inhabitants ☐ 10 – 50 000 inhabitants
☐ 50 – 100 000 inhabitants ☐ 100 - 500 000 inhabitants ☐ over 500 000 inhabitants

15) Highest reached education level:

☐ Primary school ☐ Specialized ☐ Specialized with school leaving exam
☐ Secondary school ☐ Higher school ☐ High school / University

16) Your net monthly income in CZK:

☐ 0 – 8 000 CZK ☐ 8 – 15 000 CZK ☐ 15 – 20 000 CZK ☐ 20 – 30 000 CZK
☐ 30 – 40 000 CZK ☐ over 40 000 CZK

1 EUR = 25.38 CZK (CNB 16. February 2013)

Picture 16 Paling around standard container to prevent its movement; Santa Cruz das Flores, Azores

Source: own photograph, taken 8/2012

Picture 17 Example of Underground SEMI containers

Source: Reflex Zlín, spol. s r. o.