The Environmental and Economical Feasibility of an Organised Waste Collection Scheme as a part of Integrated Waste Management System

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***Abstract*—**The current research assesses the economical feasibility of the reorganisation of municipal waste collection service as well as the impact of the organised waste collection scheme (OWCS) on source sorting and recovery of municipal waste. Municipal waste generation and recovery rates in the period of the implementation of the OWCS in Tallinn in 2005-2010 and the municipal waste collection fees were analysed. In addition, a separeate research was carried out in order to analyse the feasibility of Harju County Waste Management Centre. Tallinn City Government has recently implemented the advanced OWCS in one of the city districts with considerably positive results. In the municipalities encircling Tallinn, the administrative efficiency must be improved. The findings of the current study show that implementation of the organised waste collection scheme has contributed to source sorting and recycling/recovery of both recyclables and biodegradable wastes in Tallinn, and the reorganisation of the waste management in Harju County municipalities would improve both administrative efficiency and economical feasibility.

Keywords—biodegradable waste, economical feasibility, integrated waste management model, municipal waste, recycling and recovery.

I. Introduction

THE EU Directive 2008/98/EC (waste directive) requires that member states take measures to ensure waste undergoes recovery operations, and to develop the necessary collection systems [1]. The integrated waste management model (IWMM) involves a complex of measures and actions for waste management planning and development with the ultimate aim of minimising the environmental impact of waste and waste treatment, and contributing to the recycling and recovery of municipal waste. There are several different approaches and definitions for the IWMM; however, they all deal with the minimisation of the environmental impact of waste management using life cycle assessment as well as legislative and administrative measures, info-technological tools and the best available technologies. In this paper, the organised waste collection scheme (OWCS) and its advanced application as part of the integrated waste management model for Tallinn and Harju County municipalities are introduced. In Estonia, the organised municipal waste collection scheme was developed in order to bring municipal waste collection and treatment, including source sorting, to a new quality level that would meet the requirements of the waste directive.

The OWCS is a whole new principle of municipal waste collection that can be described as a legally forced rearrangement of the waste collection market held by private companies, and legally forced incorporation of all households to the waste collection system. Through the OWCS, recycling and recovery operations are preferred instead of the disposal of municipal waste. Also the source sorting of paper and biodegradable waste become mandatory within the OWCS, and all the households are compulsorily incorporated into the municipal waste collection system. The implementation of the system in Estonia and Tallinn began in 2005 and is still in process. Yet, in some municipalities the public procurements have failed due to the opposition of the waste companies or because of the administrative incapability.

The definition for OWCS given in the Waste Act is following: "The organised waste collection scheme is collection and transportation of the municipal waste from the predetermined waste collection district to the predetermined waste treatment facility by a waste company selected by the local authority." Waste companies enter into contractual relationship on municipal waste collection areas, appointed to them as result of public procurements, carried out by local authorities. All households are required to join the waste collection system. Supported by info-technological supervisory tools (waste holders register), the OWCS is an important administrative measure in the integrated waste management model. The advanced OWCS allows municipality(ies) or a non-profit organisation authorised by the municipality(ies) to take over the customer database so that all the waste holders become clients of the waste management centre, which would then be the only client of the waste collection company and fully responsible for the waste collection service as an administrative body [2]. In the advanced OWCS the municipality holds the separate public procurements for waste collection and waste treatment services. The municipality bills

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the waste holders and pays for the waste collection service to the waste collection company, and for the waste treatment service to the waste treatment company, thus acting as the customer service and accounting centre.

The main objectives of OWCS are: the incorporation of all the households and waste holders into the waste collection system, better control on the waste collection fee and service quality, minimisation the environmental impact of waste collection and, last but not least, development of source sorting.

In Tallinn, the extent of the experience in the implementation of OWCS is sufficient enough to draw an analysis of the advantages and disadvantages of the system. In addition, Tallinn City Government is currently (beginning of 2013) implementing the advanced OWCS, which first results are already occurring. The most critical issue in municipal waste collection in Tallinn is biodegradable fraction because the central collection and treatment of that fraction is neither economically nor environmentally cost-effective. The main problems related to the source sorting of bio-waste are related to environmental awareness and economical feasibility. Whithin the OWCS, source sorting of bio-waste become compulsory and the bio-waste collection fee was cross-subsidised on account of the mixed waste collection fee.

In the local authorities of Harju County, which altogether host almost three times fewer inhabitants than Tallinn City (153,492 *versus* 419,713), the main stumbling block is administrative inefficiency. The numbers of inhabitants of Harju municipalities (23 excluding Tallinn) range from 764 to 17,671 [8], and each of them has a fully functioning administrative body, covering public services from social assistance to road maintenance and waste management. This results in multiplicity of the administrative tasks of the public officers – one specialist must handle several problems such as the source sorting of municipal waste, environmental and waste awareness raising activities, maintenance of public areas and containers etc., while in Tallinn City Government, for example, there is a particular officer for each task.

II. Materials and Methods

A. Legislative Background

The main principles of OWCS are outlined in the national Waste Act (§ 66-69), as follows:

- the territory of a local authority is divided into waste collection districts involving approximately, in general case no more than 30,000 inhabitants;
- the licence to provide the municipal waste collection service in the district is granted for up to five years and a public procurement is held by the municipality to choose the waste company. The licence gives an exclusive right of municipal waste collection on the predetermined waste classes (usually mixed municipal waste, paper waste, biodegradable waste) to only one waste collection company, and the other waste companies are not permitted to collect those waste classes in that waste collection district unless violating the local waste regulation and Waste Act;
- the waste holders, both civilians and enterprises, are obliged to join the waste collection system at their place of residence or activity, which means that the incorporation to the waste collection system is property-based;
- exemptions are justified only by the reason that a house or real estate is not actively used in any way that would result in waste production (e.g. seasonal exemption is given when the house or cottage is used only as a summer residence and temporary exemption is given when the house is on sale or not in use in any other ways);
- the waste company provides the city with data regarding waste holders and updates the waste holders register, thereby providing frequent up-to-date feedback about incorporated and unincorporated waste holders to the local authority [2].

Regarding the National Waste Act, the percentage of the biodegradable fraction in landfilled waste has to fall to 20% by the year 2020 [2], from today's percentage of more than 50% [3,4]. Therefore, the municipalities have to take action in order to meet this target. Since the technological options for separating the biodegradable fraction from the mixed municipal waste are limited, and the incineration plant near Tallinn is under construction (it will be ready to receive waste by the end of 2013), the main available solution is the source sorting of biodegradable waste.

B. Facts and Figures

1) Waste Generation in Tallinn

The average municipal waste production per capita has decreased during the observed period from approximately 664 kilos (224,414 tons per 337,890 inh. 2002) to 496 kilos (204,435 tons per 411,980 inh. 2010) [4,5], yet the amounts of mixed waste have decreased by half. While the mixed municipal waste stream shows a steady trend of decrease, the amounts of separately collected waste have increased. This trend is in the timescale correlation with the implementation compulsory source sorting of packaging waste in 2005 and bio-waste in 2007-2008. The total amounts of municipal waste fluctuate within the observed period from 172,942 tons (minimum, 2006) to 257,186 tons (maximum, 2004). Table 1 presents the main separately collected municipal waste classes generated in Tallinn in the years 2002-2010.

Although the separate collection of bio-waste shows a good progress since the implementation of compulsory source sorting, it still needs to be improved in order to meet the targets of the Waste Act – the amounts of separately collected bio-waste should increase estimably twice by the year of 2020. As to the packaging waste, the abrupt increase of source sorting coincides with the implementation of the producer's responsibility on packaging waste. In 2005, within few month almost half a thousand public drop-off points for packaging waste were installed in Tallinn.

Table 1. Waste generated in Tallinn 2002-2010, tons [5]

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Mixed waste	220,278	213,639	213,784	186,206	153,565	150,609	131,559	112,134	106,834
Packaging	3,939	9,032	13,784	23,506	58,379	50,413	48,957	46,439	67,215
Paper waste	197	8,357	29,496	12,629	19,147	22,427	26,369	22,735	21,751
Bio-waste	0	188	122	119	172	1,048	7,113	8,820	8,635
Total	224,414	231,216	257,186	222,460	172,942	224,497	213,998	190,128	204,435

2) Public Collection Options for Recyclables

In Tallinn, any building with more than 10 apartments must have separate containers for paper waste and biodegradable waste, as well as buildings such as restaurants, markets, shops, offices where more than 25 kilos of those waste fractions per week is produced [7]. The packaging waste containers are commendatory since packaging waste is covered by the producer's responsibility. The average frequency of public packaging waste containers grid is one container per 1,000 inhabitants resulting in approximately 300 public drop-off points in Tallinn.

In addition, these lightweight packaging materials are collected with a "green bag" in the detached houses areas. There are four public waste stations in Tallinn provided by Tallinn Environment Department for recyclables (paper, metal, class, plastics, wood), domestic hazardous waste and waste covered by producer's responsibility (WEEE, end-of-life tyres, packaging). The management of both the central and public collection networks are based on the "polluter pays" principle. Although the public services are provided by city government, the budget for waste management is directly linked to and dependent on the environmental tax on landfilling municipal waste, thereby indirectly paid by the waste producers.

In Harju County, the packaging waste and WEEE are similarly collected, according to the producer's responsibility principle, through public drop-off and manned collection points. As to paper and bio-waste, separate containers are only provided in areas with a high population density [9].

3) Implementation of the OWCS in Tallinn

Tallinn with its 419,830 inhabitants [6] is divided into 13 waste collection districts. The executive authority to run the public procurements is Tallinn Environment Department. Today, the entire Tallinn municipal waste collection market is divided between 5 waste companies. Approximately 70% of inhabitants live in the areas of apartment houses and 30% of inhabitants live in the areas of detached houses. The population number and its density are inevitably important figures when organising public procurements, planning the public network of waste collection equipment and drop-off points (packaging containers, hazardous waste collection points, waste stations) and later on determining the waste collection routes.

Since March 2013, Tallinn Environment Department has been implementing the advanced OWCS step-by-step, starting with one city district, North-Tallinn, which has 56,914 inhabitants. The subsequent city districts (Haabersti, Kristiine and City Centre) that will transfer to the advanced OWCS within the coming months are home to 125,933 inhabitants [6]. All the waste holders become customers of Tallinn Environment Department, who procure the waste collection service from private waste collection companies. The Environment Department also procures the waste treatment from Estonian Energy Ltd [8], meaning the collection company no longer owns the waste, as was the case in regular OWCS; rather the municipality controls the waste flow. The first drawbacks of the advanced OWCS were revealed within few weeks, when the waste company did not reach to all the waste holders and some of the containers became overfilled, which resulted in the hullabaloo of the waste holders. However, in the next two weeks, the Tallinn Environment Department got the control over the situation.

4) Waste Management in Harju County

There are 23 municipalities, excluding Tallinn, in Harju County, with the population and size of the territories ranging from 764 to 17,673 inhabitants and from 4 to 708 km^2, respectively (Table 2) [10]. Five of the municipalities represent towns, while the remainder are parishes with village centres and mainly dispersed settlement. Although the Waste Act allows to form waste collection districts which involve up to 30,000 inhabitants, in Harju County each municipality forms a separate waste collection district. In most Harju municipalities, OWCS and the source sorting of recyclables have been implemented over an environmentally and economically sound range. Compulsory waste collection and source sorting is only applied in settlements. The households that are far from villages and to where the roads have limited load-bearing capacity or are seasonally impassable, are not involved in the collection scheme, meaning they have to organise their own waste management [9].

The waste management situation in Harju municipalities was mapped within the project "Development of waste management cooperation in Harju County Municipalities" by questionnaires addressed directly to the waste specialists working at the municipalities (quantitative data) and oral interviews with six selected specialists (qualitative data). The questionnaires involved detailed information about source sorting options (domestic hazardous waste, recyclables, packaging, WEEE, bio-waste), public procurements of OWCS (problems and opposition during the procurements, tender evaluation models and criteria, data about contracts and contractors), the number and sizes of the containers used in the municipality, their emptying intervals and the waste collection

fees [9]. The mentioned questionnaires and interviews were the main input data for the socio-economical cost-benefit analysis of the Harju County waste management cooperation centre [11].

Table 2. Harju County municipalities [10]

Municipality	Inhabi-tants	Territory km^2	Population density inh/km^2
Anija	5,853	520.9	11.2
Harku*	13,064	159.1	82.1
Jõelähtme*	6,167	210.9	29.2
Keila	4,846	178.9	27.1
Keila town	9,918	11.3	881.4
Kernu*	2,052	174.7	11.7
Kiili*	4,588	100.4	45.7
Kose*	5,725	237.3	24.1
Kuusalu	6,766	707.9	9.6
Kõue	1,589	295.5	5.4
Loksa town	2,907	3.8	763.8
Maardu town	16,358	22.8	718.6
Nissi*	3,018	264.9	11.4
Padise*	1,789	366.6	4.9
Paldiski town	4,093	60.2	68.0
Raasiku*	4,709	158.9	29.6
Rae	13,838	206.7	66.9
Saku	9,185	171.1	53.7
Saue	9,918	195.2	50.8
Saue town	5,973	4.4	1,361.5
Vasalemma	2,701	38.7	69.9
Viimsi*	17,671	72.8	242.6

* members of Harju Ühisteenuste Keskus

C. Waste Holders Register as a Tool for Supervisory and Statistics

The register of waste holders is a web-linked interactive database, which has connections to other national registers like that of properties, buildings and population. The objectives of the register are to collect data pertaining to:

- waste holders who are incorporated into or exempted from the waste collection system;
- waste generating sites, waste classes generated and waste containers in use on those sites;
- waste collection companies to whom the monopoly of waste collection has been given.

Ideally, the waste holders register consists of detailed data about the waste generation site (private house, apartment house, how many apartments, business or social building, etc.), status of the waste holder, expiry date of exemption, containers in use on the particular waste generation site by waste classes and the frequency of emptying the containers.

The data described above gives the basis for systematic supervisory both on the waste collection company as well as on the waste holder. In addition to the detailed data about a waste generation site, the register can draw summaries about waste generation sites or containers or exemptions or any other data in the register within city districts, waste collection districts or streets. The database of the register of waste holders is shared with the contractors so that the contractor has the overview of the waste generation sites that are incorporated into the waste collection (the existent clients) as well as those that are still outside of the system (potential clients). Taking over the waste holders who are not incorporated into the waste collection is within the responsibility and interest of the waste company.

1) Tallinn Waste Holders Register

According to the data of the Tallinn waste holders register, there are 32,043 waste generation sites in Tallinn including private houses, enterprises and apartment houses, and approximately half of them are private houses (ca 15,000). Compared to the regulation of free market, approximately 2,000 households which were out of any collection system have been incorporated into the organised waste collection system. The number of containers for bio-waste, paper and mixed municipal waste collection are, as follows:

- bio-waste ca 2,841 containers with total volume of 529 cubic metres;
- paper waste ca 3,887 containers with total volume of 2,860 cubic metres;
- mixed waste ca 23,393 containers with total volume of 11,695 cubic metres [12].

The reason why the number of mixed waste containers is smaller than the number of waste generation sites is that many dwellings have common waste containers [12].

2) Waste Holders Registers of Harju County Municipalities

Of 23 Harju municipalities, 13 had relevant and appropriate waste holder registers suitable for data analysis. The data consist of the number of each type (0.08-4.5 m^3) of container with the emptying intervals and collection fees for mixed municipal waste, paper waste and bio-waste [10]. Based on the data of waste holders' registers, the annual turnover of waste collection fees and the volumes of municipal waste generated in each municipality were calculated.

D. The Socio-Economical Cost-Benefit Analysis of the Waste Management Cooperation Centre of the Harju County Municipalities

The analysis was carried out by the Estonian Centre for Applied Research (CentAR) in cooperation with WasteBrokers LLC, which managed the project. CentAR compiled the financial and socio-economic analysis and the quantitative portion of the risk analysis. WasteBrokers compiled the analysed scenarios, mapped the qualitative impacts and put together the qualitative part of the risk analysis. The objective of the analysis was to estimate if and what kind of waste management expenses could be retrenched by the

reorganisation of waste management in Harju municipalities through a waste management cooperation centre (WMC) and implementation of the advanced OWCS. The European Commission's methodology for the cost-benefit analysis of investment projects was used for the analysis.

In the analysis, three scenarios were assessed:

1) Basic Scenario (S0) – the waste management is organised as it was before.

2) Limited Project Scenario (S1) – only part of the projected actions is carried out. The municipalities delegate particular waste management duties to the WMC. For example, the public procurements are organised in cooperation and for enlarged/united waste collection districts by the WMC which reduces the administrative load in municipalities. Also the public collection network for sorted waste is taken over by WMC as well as public awareness raising activities. The financing model of the public waste management services is based on the budgets of the municipalities, and the municipal waste collection fees are paid straight to the waste company by waste holders.

3) Full-scale Project Scenario (S2) – in addition to S1 scenario, the advanced OWCS is applied which redirects cash flow from waste ~~holder~~ to waste company to waste holder→WMC→waste company. Part of the public waste management expenses (awareness activities, domestic hazardous waste collection, waste holders register) is integrated into the waste collection fee as administrative expenses.

The cash flows of the project scenarios (S1 and S2) were analysed and compared to the basic scenario (S0). As a result of the comparison, the financial retrenchment for the municipalities from the implementation of the project scenarios was determined (Financial Net Present Value, FNPV). In addition, the financial benefit for the waste holders from the implementation of one or other project scenario was calculated (Expanded Financial Net Present Value). Through this approach, cash flows were analysed from the point of view of the waste holders. The analysis facilitates planning quality improving actions in a cost-neutral way, which means that if a project scenario is to be realised, the project is considered to be beneficial or at least cost-neutral as long as the Net Present Value of the costs of any additional activities do not exceed the FNPV of a project scenario.

III. Results and Discussion

A. The Composition of Municipal Waste

According to research carried out in 2008 in Estonia by Stockholm Environment Institute Tallinn, which was carried out in several different municipalities including Tallinn, the mixed municipal waste going to landfill still contains remarkable amounts of packaging, paper and bio-waste [3]. The fractional composition of mixed municipal waste has changed significantly during the relatively short period from 2005 to 2008 (Figure 1). Due to the rapid economic growth and increased consumption levels, the share of packaging waste in total MSW has increased from 26% in 2005 to 37% in 2008. This is also the reason why the total percentage of packaging related materials (plastic, glass and paper/cardboard) appears to have increased significantly, while the share of organic waste (food and garden waste) has decreased [4]. Figure 1 below reflects the changes in Estonia, including Tallinn, that were involved in the research.

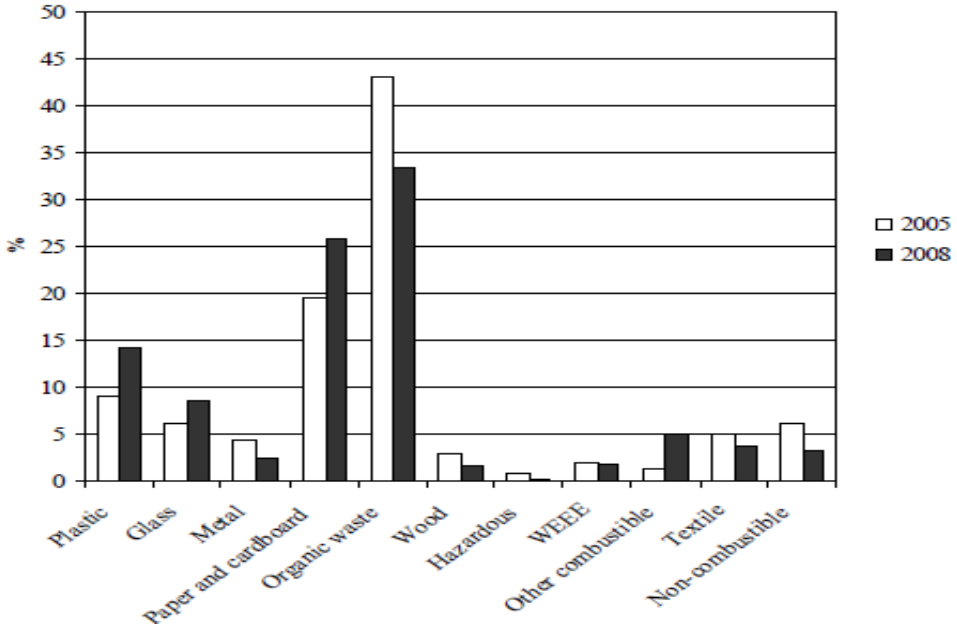

Fig 1. Changes in MSW composition 2005-2008 [4]

From Figure 1 two waste fractions – paper waste and organic waste – are clearly outstanding. As to paper waste, the increase of this fraction in the mixed waste can be identified and on the contrary, a decrease in the biodegradable fraction is present. The first phenomenon, the increase of the paper waste fraction in mixed waste, can be explained by the increased consumption of paper towels, paper bags, throwaway plates and other products, the popularity of which has increased due to the growth in economic (one-time products) and environmental awareness (paper instead of plastics). The decrease of the organic waste stream in mixed waste can be explained by making compulsory the source sorting of organic kitchen waste in Tallinn in 2007-2008 within the implementation of the OWCS.

B. The OWCS's Effect on Source Sorting

Regarding the SEIT 2008 research, mixed municipal waste still contains at least 33% of organic waste and 26% of paper and cardboard [3]. Compared to the year 2005, the annual mixed waste generated in 2008 has decreased by 30% while the amounts of source sorted recyclables show a steadily rising trend (Figure 2).

The peak of total municipal waste generation of the observed period (2002-2010) was in 2006 and then turned into steady decrease as shown in Figure 2. In 2005, the producer's responsibility of packaging waste was implemented in Estonia resulting in a dramatic increase in source sorted packaging waste in 2006. However, since then, the amounts of separately collected packaging waste have decreased, which can be explained by the growth of environmental awareness and decrease in consumption. Both separately collected paper waste and organic waste show an increase, especially that of bio-waste, from almost non-existing to approximately 8.1% of mixed municipal waste in 2010.

As referred to in section II C., the number of bio-waste containers has reached 3,000 with a total volume of 530 cubic metres. Those containers came into use in Tallinn within two years (2007-2008). Unfortunately, it is not known how many dwellings with less than 10 apartments practise the home composting of bio-waste in their backyards. Based on Moora, it could be assumed that approximately 3% of the total MSW generated in 2005 was composted at home [4]. In his PhD thesis, Moora came to the conclusion that composting has hardly any advantages with respect to the environment and energy turnover in comparison to other waste recovery options (such as recycling and incineration). However, composting has a potential if landfilling is avoided and incineration or anaerobic digestion are not feasible [4]. Up to the end of 2013, incineration will be not available in Estonia; therefore, the source sorting and central composting of bio-waste is still relevant.

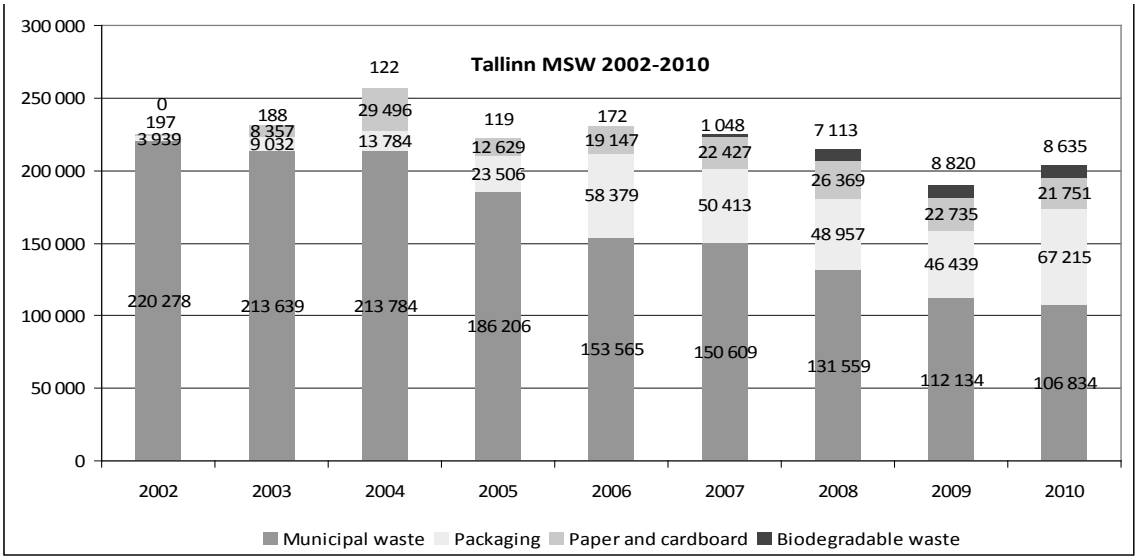

Fig 2. Waste generated in Tallinn 2005-2010, tons (Statistics Estonia 2011)

In their analysis of collection systems for sorted household waste in Spain, Gallardo et al. (2012) found that the best system for source sorting is the door-to-door collection of mixed waste, organic waste and multiproduct, and the collection of glass at drop-off points [13]. Although the analysis focused on source sorting in Spanish towns with inhabitants from 5,000 to 50,000, the results can be extrapolated and used in comparison with different Tallinn city districts. In Tallinn, similarly, organic waste, paper, mixed waste and sometimes also light-weight packaging materials are collected door-to-door, while glass and the majority of packaging waste is collected at drop-off points.

C. Cost-effectiveness of OWCS

Since the implementation of OWCS waste collection fees within OWCS have decreased compared to the free market prices due to the pressure of the public procurements. There are two main reasons why the average waste collection fees on the free market are approximately 30% higher than those in OWCS.

First, the collection fees are generated in conditions of tight competition in order to outplay the competitors, which results in a lower gross margin. Although the waste companies have different financial management, the basic costs of waste collection and treatment are the same for all the contenders; this means in order to win the competition the tenderer also has to cut the prospective profit. The second reason for lower prices in OWCS stands in the optimisation of waste collection logistics. Since all the waste holders are incorporated and thereby located closely, the collection routes are more economical and can be adjusted/optimised more flexibly within the area. In addition, for the waste company a defined number of customers and turnover are granted for a certain period, which helps to economise all the investments to the techniques and other equipment. Since there is no more competition for the market share, the waste company can also cut the advertising expenses. All together, this enables the deduction of collection fees.

Rhoma *et al.* 2010 studied the importance and role of the MSW collection problem from an economical and environmental prospective. They presented a MSW logistic model to determine the total costs per ton and examine the effect of different scenarios, such as different service options and different types of vehicle. The results from those different models give a different investigation but all the results show that vehicles and manpower play a big role in waste logistics costs. Moreover, using this model gives the municipal authority the opportunity to control all the waste management activities in advance. Collection and transport is the field of waste management in which effective measures aimed at cost reduction can be taken. For example, a reduction in waste generation may reduce collection costs if fewer trucks, workers and routes are required [14].

Regarding the study carried out in Bosnia and Herzegovina, the issues that can potentially affect the implementation of a separate collection system were the people's lack of confidence towards the public utility in charge of the management of the service, as well as complaints about an unfair taxation system. 94% of the interviewees feared that the new separate collection system would have been irregular and poor, like the current one. Moreover, 63% also asserted that people not subjected to the taxation system would have disposed of their wastes in selected collection points, if a kerbside system was used. These attitudes and opinions were considered while choosing and designing the collection system, for example in terms of type and frequency of collection and for waste fractions to be collected [15]. Similar attitudes and problems were also faced while implementing OWCS and source sorting in Tallinn.

In the Harju County municipalities, the waste collection fees, depending on the size of the container, can differ by many times. The reason as to why e.g. the emptying fee of an 80 or 140 litre container differs significantly (Table 3) in neighbouring municipalities, is due to the tender evaluation model, which in most cases was the Merit Point system [10]. The main weakness and inadequacy of the Merit Point system in terms of waste collection procurements is that it does not take into account the different components of the waste collection fee and allows tenderers to play the evaluation system, resulting in extreme cases where the fee for a smaller container was higher than the fee for a bigger.

Table 3. Collection Fees in Harju County [10]

	Container (m3)	Average (€)	Max (€)	Min (€)
MSW	0.08	1.35	3.58	0.15
	0.14	2.12	3.79	0.40
	0.24	2.78	4.33	0.60
	0.37	3.41	5.95	1.50
	0.6	4.57	6.63	1.94
	0.8	5.81	9.59	3.24
	2.5	14.71	22.62	6.92
	4.5	25.20	39.71	8.18
Bio-waste	0.08	0.45	1.85	0.00
	0.14	1.34	3.58	0.00
	0.24	2.25	5.75	0.00

According to the Waste Act (§ 66) the waste collection fee must be sufficient to include the costs of building, operating, closing down and maintain a waste treatment facility, and the transportation costs of waste, and the costs of administration or preparation of waste transportation [2]. The cross-subsidisation of waste treatment costs between different container types is not directly forbidden, however this is at variance with the “polluter pays” principle. Thus, the Merit Point system is not relevant as the evaluation model for the waste collection procurements.

D. Cost-effectiveness of advanced OWCS

1) The Waste Management Centre of Harju County Municipalities

The main results of the socio-economical cost-benefit analysis for the Waste Management Centre of Harju Copunty Municipalities are, as follows: From the point of view of the municipalities, both of the project scenarios (S1 and S2) are worth realising compared to the basic scenario (S0). The FNPV is larger than zero in both cases, meaning the municipalities can financially win from the reorganisation of waste management through the cooperation centre. In terms of scenario S1, the benefit is 1.2 million euros, which arises from administrative efficiency, since the WMC can do the same work with fewer officers. In scenario S2, the financial benefit

for the municipalities is even bigger, approximately 4.7 million euros, mainly due to the integration of the public service costs that are financed by the municipalities to the waste collection fees, while the income of the municipalities does not decrease as a result of this transmission (Table 4).

The financial profitability (expanded FNPV) for the waste holders is different from that of the municipalities. The implementation of scenario S2 is accompanied by larger costs (investments, loan interest, VAT) while scenario S1 could provide most of the benefits arising from the reorganisation of waste management through the WMC, with less expense.

Table 4. The Investments Profitability Index

Senarios	S1-S0	S2-S0
Financial Net Present Value (FNPV) (thousands €)	1,238.2	4,715.5
Expanded FNPV (thousands €)	3,036.4	1,357.6

The benefit, regardless of which project scenario would be imlemented, arise mainly from three circumstances:

1. the improvement of the administrative efficiency – the WMC is capable of doing the work of the municipalities with less number of emploees;
2. the optimisation of waste collection logistics and transportation – instead of 23 municipalities and waste collection districts, the enlarged overboundary waste collection districts are formed between several municipalities;
3. tighter competition at the public procurements – the separation of waste collection and treatment services enable smaller transportation companies to enter the waste collection market, breaking down the vertical monopolies.

It is a key factor for the local authorities that the scenario S2 enables to launch a new financial source for some of the waste management public services. In addition, there are other qualitative impacts, which emerge especially in case of scenario 2, however those are not possible to measure in quantitave criterias. The main qualitative aspects are as following:

- the waste holder gets a long-term contract partner as the waste management centre independant of the waste collection procurements and service providers. The WMC provides the waste holder with the waste collection service, customer service, waste managment information and councelling, including solvation of the current problems and complaints on the waste collection or the information about the public collection options for source sorted waste;

- the quality, price level and availablity of the waste collection fee are equalised all over the Harju County, both in village centres and perifery, independant on the waste collecting company or waste collection district;

- since the costs of the public waste stations and hazardous waste collection points are integrated to the municipal waste collection fee, the waste holders are also motivated to use this "free of carge" public network.

In response to the results of the project and the analysis, Harjumaa Ühisteenuste Keskus (HÜK), a non-profit waste management cooperation organisation, was established in June 2012 by nine Harju County municipalities comprising 58,783 inhabitants. To date, HÜK is gradually taking more responsibility and waste management tasks from its members.

In their study of modelling Integrated Waste Management System (IMSWMS) of the Czech Republic, Hrebicek and Soukopova combined four sub-models: a) the transport sub-model of MSW flows among sources and facilities using the geographic information system (GIS); b) the waste production sub-model; c) the cost economic sub-model waste treatment facilities; and d) the carbon emissions optimisation sub-model, which facilitates choosing either the economic or environmental point of view. They used the properties of the MS Excel spreadsheet for the integration of the described sub-models into one model of the IMSWMS of the Czech Republic. This enabled them modelling the cost and price relationships for the municipal solid waste management of the country through the central option of the set of the input economic parameters of sub-models at the single control sheet of the MS Excel with interconnected sheets, where they implemented the described sub-models [16]. Similar to the first three (a, b, c) sub-models of Hrebicek and Soukopova, the same components were also used in the Harju County WMC cost-benefit analysis in order to calculate the projected turnover of the waste collection and treatment services.

2) The advanced OWCS in Tallinn

The public procurements to select the service providers for pilot city districts where the advanced OWCS was to be implemented were organised in two parts: first, the procurement to find the waste treatment company was organised, followed by the waste collecting companies for each collection district.

Even if the Tallinn Environment Department established a new administrative body, the waste management customer centre, the procurements resulted in general if not cheaper waste collection fees than previously then at least close to average waste collection fee in Tallinn (Table 5).

The case of Tallinn's new OWCS has proven that the separation of two waste management operations, treatment and collection, can make waste collection fees not only more transparent but also cheaper in some instances [17,18]. In addition, due to the separation of treatment and collection services, the municipality obtains control over the waste flow and treatment operation, thereby contributing to recycling and recovery.

Table 5. The Examples of Waste Collection Fees in Tallinn [17,18]

Container (m^3)	New fee in pilot districts 2013 (€)	Min. fee in pilot districts 2012 (€)	Max. fee in pilot districts 2012 (€)	Average fee in pilot districts 2012 (€)	Average fee in all districts 2012 (€)
0,14	2,34	1,53	4,00	2,72	2,46
0,24	2,58	2,35	4,95	3,40	2,93
0,8	5,40	4,63	8,25	6,52	5,67
1,1	7,14	6,12	7,14	6,63	6,06
2,5	16,14	11,58	21,93	17,73	15,02
4,5	24,00	20,84	34,51	28,04	24,76
0,24 Bio-waste	2,58	1,53	4,22	3,27	3,19

The proposed method of Chalkias and Lasaridi (2009) utilises various geographical data (road network, location of waste collection bins, land use, etc.) in combination with advanced GIS-based spatial analysis. The implementation of the proposed method focused on the re-design of the waste collection bins system as well as on the investigation of an optimal collection routing scenario. Their results demonstrate that the proposed scenario is significantly efficient in terms of collection time and distance covered (20% and 12.5% improvement, correspondingly) with consequent gas emissions and fuel consumption savings [19].

IV. Conclusions

Regarding the targets from legislation, the percentage of biodegradable fraction in the waste going to landfill has to decrease to 20% by the year 2020 [2]. In Tallinn, the OWCS as an administrative measure has been implemented and the source sorting of bio-waste has become mandatory within the OWCS. Today, the register of waste holders works as a supporting virtual tool for supervisory purposes and gives detailed information about every property and waste holder in Tallinn [12].

The composition and quantities of municipal waste have changed within the few last years due to the implementation of a producer's responsibility on packaging waste as well as the source sorting of paper and bio-waste [3,4,5]. The main trends that can be drawn observing waste generation data in Tallinn between 2002 and 2010 are, as follows:

- amounts of mixed municipal waste have generally decreased due to source sorting;
- amounts of separately collected paper and bio-waste have increased;
- amounts of packaging waste have slightly decreased since 2006.

The source sorting of biodegradable waste and recyclables like packaging and paper waste has improved due to the implementation of organised waste collection, which has been supported and accompanied by massive public awareness campaigns. Despite this, separate collection and central collection of bio-waste still have to increase dramatically within the coming years in order to meet the targets from legislation, unless an incineration plant is built and becomes operational. The main disadvantages of home composting compared to central composting are uncontrolled process and the inconvenience for the close neighbourhood [20]. In order to meet the targets set for the reduction of the biodegradable fraction in municipal waste going to landfill, a massive reorganisation of waste management has to take place within the coming years.

The OWCS has incorporated many households that were out of any waste collection before. A direct result of the implementation of the organised waste collection scheme has been a decrease in the littering of green areas and the surroundings of public containers within the first few months. In addition, the waste collection logistics have been optimised and the environmental impact of waste transportation has been reduced. Compared to the free market, the waste collection fees within the OWCS are lower and stable.

The main objective of implementing an environmental management system is to reduce the impact on the environment of activities, products and services of organisation. The most important are increasing profits by optimising the use of resources (raw materials, energy), by improving waste management and reducing the costs of any environmental incidents [21].

The separation of waste treatment and collection in public procurements facilitates better control of waste flow and treatment operations as well as a more transparent waste collection fee. The implementation of the advanced OWCS results in a shift of some administrative functions (customer service, accountancy) from the waste company to the municipality, which enables better control on the quality of the waste collection service.

As to the Harju County municipalities, the waste management cooperation centre would increase the cost-effectiveness and administrative efficiency of waste management. In addition, the implementation of the advanced OWCS would reduce the expenses of the public waste management services by the transmission of those costs to the

waste collection fees that are in full accordance with the "polluter pays" principle.

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