THESIS ON CIVIL ENGINEERING F47

Integrated Economic and Environmental Impact Assessment and Optimisation of the Municipal Waste Management Model in Rural Area by Case of Harju County Municipalities in Estonia

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any academic degree.

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Hajaasustusala jäätmehooldusmudeli majandusliku ja keskkonnamõju hindamine ning mudeli optimeerimine Eestis Harjumaa omavalitsuste näitel

JANA PÕLDNURK (end. KIVIMÄGI)

TTÜ KIRJASTUS

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ABBREVIATIONS

avg.	average
BSE	Board of Statistics of Estonia (Statistikaamet)
BW	bio-waste incl. biodegradable kitchen waste List of wastes code 20 01 08 and compostable garden and park waste List of wastes code 20 02 01
CBA	cost-benefit analysis
CHP	combined heat and power
DSS	Decision Support System
EC	European Commission
EEIC	Estonian Environment Agency, Environmental Information Centre (Eesti Keskkonnaagentuur, Keskkonnainfo)
EKT	Estonian Environmental Services Ltd (AS Eesti Keskkonnateenused)
EME	Estonian Ministry of the Environment (Keskkonnaministeerium)
EP	the Parliament of the Republic of Estonia (Riigikogu)
EU	European Union
FNPV	Financial Net Present Value
GHG	greenhouse gases
GIS	Geographic Information System
HOL	Union of Harju County Municipalities (Harjumaa Omavalitsuste Liit)
HÜK	Communal Services Centre of Harju County (MTÜ Harjumaa Ühis-teenuste Keskus)
IEJHK	Eastern Estonian Waste Management Centre (MTÜ Ida-Eesti Jäätme-hoolduskeskus)
inh.	inhabitants
ISM	interpretive structural modelling
IWMM	Integrated Waste Management Model
KEJHK	Central Estonian Waste Management Centre (MTÜ Kesk-Eesti Jäätmehoolduskeskus)
KOP	portal of the local authorities of Estonia (Kohalike Omavalitsuste Portaal)
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LVOL	Union of Western Estonia Municipalities (Läänemaa Omavalitsuste Liit)
MBT	mechanical-biological treatment
MMW	mixed municipal waste, List of wastes group 20 code 20 03 01
MPS	merit-point system
MSW	municipal solid waste, List of wastes group 20
OWCS	organised waste collection scheme
PAYT	Pay As You Through
PC	paper and cardboard, List of wastes code 20 01 01
PPP	public-private partnership
psg.	passage

RCV	refuse collection vehicle
RDF	refuse derived fuel
RJKK	Rapla County Waste Management Centre (MTÜ Raplamaa Jäätme-käitluskeskus)
RS	Ragn-Sells Ltd (Ragn-Sells AS)
S0	Base Scenario, existing situation
S1	Project Scenario 1, limited scale scenario
S2	Project Scenario 2, full-scale scenario
SUSBIO	Sustainable utilisation of waste and industrial non-core material
TRC	Tallinn Recycling Centre Ltd (AS Tallinna Jäätmete Taaskasutus-keskus)
VPKK	Valga County Environment Centre (SA Valga Piirkonna Keskkonna-keskus)
WAMPS	Waste Management Planning System
WEEE	waste of electrical and electronic equipment
WMAP	Waste Management Action Plan
WMC	Waste Management (Cooperation and Competence) Centre

LIST OF PUBLICATIONS INCLUDED IN THE THESIS:

This thesis is based on the following six original publications, which are referred to in the text as Paper I, Paper II, Paper III, Paper IV, Paper V and Paper VI.

Paper I: Kivimägi, J. 2011. A descriptive analysis of post-closedown environmental monitoring and maintenance of the Pääsküla landfill. Management of Environmental Quality: An International Journal, 22(6). Pp 769 – 786.

Paper II: Kivimägi, J., Loigu, E. 2013. The Environmental and Economic Feasibility of an Organised Waste Collection Scheme as a part of Integrated Waste Management System. International Journal of Energy and Environment 2013, vol 7. Pp 178 - 187. ISSN: 2308-1007. North Atlantic University Union (NAUN).

Paper III: Põldnurk, J. 2014. The reorganisation of waste management in Harju County municipalities through a waste management cooperation and competence center. A socio-economic feasibility study. European Scientific Journal 2014, vol 10(5). Pp 382-399. ISSN: 1857-7881.

Paper IV: Blonskaja, V., **Põldnurk, J.**, Loigu, E.
Utilisation options for biodegradable kitchen waste in Estonia. A SWOT analysis. Proceedings of the 9th International Conference "ENVIRONMENTAL ENGINEERING" 22–23 May 2014, Vilnius, Lithuania. SELECTED PAPERS. eISSN 2029-7092 / eISBN 978-609-457-640-9.

Paper V: Põldnurk, J. 2014. The impact of tender specifications and evaluation model of the waste collection procurement on the waste collection fees. International Journal of Economics and Statistics 2014, vol 2. Pp 277-287. ISSN: 2309-0685. North Atlantic University Union (NAUN).

Paper VI: Põldnurk, J. 2014. Optimisation of the Economic, Environmental and Administrative Efficiency of the Municipal Waste Management Model in Rural Areas. Submitted to Resources, Conservation and Recycling. ISSN: 0921-3449. Elsevier. Status: under review.

These papers or the original ideas of the papers have been introduced by the author on the following international or local conferences:

1. Tallinn, Estonia 27.02.2014 Waste Seminar by the Estonian Association of Municipal Engineering Upgrading Waste Management – Oral presentation "The Environmental impact of Waste Management Decisions"
2. Interlaken, Switzerland, 23.02.2014 EUROPMENT 2014 International Conference on Economics, Management and Development (EMD '14) – Oral presentation "Formation of the waste collection fees within the advanced organised waste collection scheme"

3. Tallinn, Estonia 08.12.2011 SEI (Stockholm Environment Institute) Tallinn conference Human Impact on Tallinn Environment IV – Poster "Options of reducing the environmental impact of waste management in an urban environment by means of source sorting and optimising the collection scheme by the example of Tallinn"
4. Tallinn, Estonia 20.05.2011 LIFE+ Environment Policy & Governance HEC-PAYT Project The development of Pay as You Throw Systems in Hellas, Estonia and Cyprus Implementation of the PAYT waste collection charging model in Estonia – Oral presentation "Formation of waste collection fee within organised waste collection system"
5. Štrbské Pleso, High Tatra, Slovakia 12-14.10.2010 The 4th annual international experts' conference "Enviro-management 2010 Landfills in Europe & Waste Management – Oral presentation "Closing down Pääsküla Landfill"
6. Heraklion, Créte, Greece 29.06-02.07.2010 ORBIT 2010 Conference Organic Resources in the Carbon Economy – Oral presentation "Organised Municipal Waste Collection Scheme as Administrative Tool for Recycling and Recovery"

Author's Contribution to the Publications

Paper	Original idea	Study design and methods	Data collection and handling	Contribution to result interpretation and manuscript preparation	Responsible for result interpretation and manuscript preparation
I	+	+	+		+
II	+	+	+		+
III	+	+	+		+
IV		+		+	
V	+	+	+		+
VI	+	+	+		+

1 INTRODUCTION

The aim of the thesis was to draw environmentally and economically optimal municipal waste collection and treatment scheme for the municipalities with low population density, where the rural areas are prevailing, to analyse the efficiency of source sorting and central collection of paper and biodegradable kitchen and green waste (hereafter bio-waste, BW), and to assess the improvement of administrative and financial efficiency of waste management arising from inter-municipal cooperation in rural municipalities by case of Harju County municipalities in Estonia. An excel-based tool was invented to evaluate the economic, environmental and administrative impacts of the current and projected waste management models. Morrissey and Brown (2004) having been reviewed different types of models used in the area of municipal waste management stated that while many models recognise that for a waste management model to be sustainable, it must consider environmental, economic and social aspects, no model examined considered all three aspects together in the application of the model. In the current thesis, environmentally, economically and socially integrated approach is applied on the system optimisation.

The main principles and requirements of waste management in EU are set in the Waste Framework Directive (EC, 2008a). The Article 4 of the directive determines the order of waste hierarchy as following: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery or composting; and (e) disposal. When applying the waste hierarchy, the EU Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste (EC, 2008a). These requirements should encourage the municipalities as the stakeholders of public waste management to analyse the economic and environmental feasibility of source sorting, central collection and recycling of some particular waste classes, such as biodegradable kitchen waste or paper and cardboard. In specific conditions, it may not be environmentally sound to follow the preferred order of waste hierarchy while deciding over the treatment operation or collection scheme. However, the Waste Framework Directive sets also some strict targets and duties on the EU member: by the year 2015 separate collection must be set up for at least paper, metal, plastic and glass wastes, and by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households shall be increased to a minimum of overall 50% by weight (EC, 2008a). Thus, regarding paper waste the Directive leaves no other option than implement and improve the source sorting of that waste class.

The Directive also sets the general principles on national legislative processes. Member States shall ensure that the development of waste legislation and policy is a fully transparent process, observing existing national rules about the consultation and involvement of citizens and stakeholders. General environmental protection principles of precaution and sustainability, technical feasibility and economic viability, protection of resources as well as the overall environmental, human health, economic and social impacts must be taken into account, in accordance with Articles 1 and 13 of the Directive (EC, 2008a).

When planning a sustainable waste management model the environmental, economic and social aspects must be taken into consideration. The environmental impact of the municipal waste management stands mainly in waste treatment methods, depending on particular technology, but the transportation of waste may contribute to the adverse environmental impact as well, if the distances within and between the collection areas and treatment facilities are long, which is the case in rural municipalities.

The main direct impacts of waste management are air emissions, and leachate of the hazardous or toxic compounds to the soil, surface water and groundwater. Air pollution is mainly caused by formation of greenhouse gas (GHG) emissions from landfills and other waste management practices such as waste incineration, recycling, and collection of MSW. Moreover, landfilling of MSW can contribute to soil and groundwater pollution by forming leachate. Such kind of environmental impacts can be significant if the share of biodegradable fraction in MSW is high and climate is relatively humid, as in Estonia (Voronova, 2013).

The main economic aspect of the municipal waste management manifests in waste collection scheme which can be optimised through logistics and administration. The efficiency of the whole waste management model in a municipality depends on the administrative performance and the competence of the municipal officials. It is obvious that a specialised administrative body like a cooperation organisation can perform far higher competence than individual multi-tasked municipal officials. Once an optimal waste collection and treatment scheme is built up, it can contribute to the recycling as well as to the cleaner environment.

The social aspect of waste management is composed of the public environmental awareness, and willingness to contribute to the recycling through the source sorting of waste, but is also limited with the range of economical cost-effectiveness. The composition of the municipal waste is inter alia influenced by the collection scheme. While working in the Waste Management Division of the Tallinn Environment Department the author planned the collection of the source separated recyclables, and implementation of the organised waste collection scheme in Tallinn. Source sorting of bio-waste was made compulsory within the OWCS. Recent results of waste reports show that within few years the separate collection of biodegradable kitchen waste have increased from non-existing to nearly 10,000 tons per year, and the percentage of bio-waste in the mixed municipal waste has slightly decreased. Thus, environmentally sound collection scheme also contributes to the reduction of environmental impact of the waste management.

The subject of biodegradable waste treatment is actual, because by the year of 2020 the municipal waste going to landfill may consist no more than 20 per cent of biodegradable fraction in it (EP, 2004a). Recent researches about the composition of municipal waste have revealed that residual waste disposed in landfill today consists averagely of 48 per cent of biodegradable waste including paper and cardboard (Moora, 2013). According to the waste management hierarchy any recycling or recovery operations must be preferred to disposal. Aerobic composting or anaerobic digestion is available only to the source separated bio-waste. Since 2013, incineration of the municipal waste is available as treatment option in Estonia. Iru Combined Heat and Power (CHP) MSW incineration plant is located next to Tallinn, and from the aspect of abovementioned restriction on bio-waste disposal, it offers the technological solution. However, considering the waste hierarchy and current source sorting practice in Estonia, the subject is still actual. The environmental and economic feasibility of source sorting and central collection of bio-waste is in focus of the current thesis.

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. Since 2005, the organised waste collection scheme (OWCS) has been applied step by step in the Estonian local authorities (Paper II). The definition for OWCS given in the Estonian 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 local authority (EP, 2004a). The objectives of the OWCS are to incorporate all the households and waste holders into the waste collection system, to gain better control on the waste collection fee and service quality, to minimise the environmental impact of waste collection, transportation and treatment, and to develop source sorting of municipal waste (Paper II). Unfortunately, the local authorities in Estonia have not applied all the opportunities and attributes of the OWCS in practice, and in several cases the duty of implementing the OWCS in its territory has been fulfilled merely formally. In the current thesis, the OWCS, its advanced form, and its benefits are analysed in details.

Having worked in Tallinn City Government for 7 years, particularly on the waste management administration, and currently still active as a consultant and project manager in the same field, the author emphasis that sustainable waste management system which would base on the best available technologies, and consider the legislative background and waste hierarchy needs to be built up in Estonia. In the municipalities like Tallinn and some other bigger towns the competition in the municipal waste collection market is tight enough due to the higher concentration of waste. But in the rural areas, the OWCS has not worked out the best, and in many cases the OWCS is nothing else than just an exclusive right of waste collection service given away to a waste company at a weak competition, while the municipality comprises no control over the waste flow nor service quality. The author dares to state that this is due to the multiplicity of the local authorities, low population density (= low waste concentration in space), and administrative inefficiency. The structure of the population density on the Estonian territory is rather unequal. Comprising only 1.3 million inhabitants on about 43,000 square kilometres, one third of the Estonia's population is hosted at the capital Tallinn. This raises the average population density in Harju County (134.5 inh./km^2) approximately 8 times higher than in rest of the Estonia, leaving there less than 17 inhabitants per square kilometre (KOP, 2014; KOP, 2011)), and turns most of the Estonian municipalities into peripheries. After excluding Tallinn, Harju County is still more populated than the rest of Estonia, but yet closer to the average profile. The administrative efficiency, regarding the number of officials responsible for waste management tasks per number of inhabitants, is 4.4 times lower in Harju County municipalities compared to that of Tallinn! Same time the officials in Harju County municipalities struggle in the multiplicity of the waste management and other public maintenance related tasks whilst in Tallinn each official is specialised to one particular task, which consequently raises the level of competence.

From the abovementioned situation arises the key issue of a sustainable waste collection model in a rural area – the optimisation of the waste collection scheme and administration from the environmental and economic aspect. In the current thesis two waste management scenarios on the present background of Harju County waste management are drawn and analysed, as well as the practical solutions are offered in order to reduce the environmental and economic impacts of waste management in the rural municipalities. In the peripheries, under the conditions of free market the waste collection service would hardly be available for a reasonable price since the waste transportation costs would make the service economically unfeasible. The OWCS can equalise the waste collection fees and availability of the service in peripheries through enlarged and conjoint waste collection districts, and cut the waste collection transportation costs. Cooperation between the municipalities can improve remarkably the administrative efficiency and reduce the financial load of waste management on the municipal budgets. If the OWCS is applied at full scale and in the advanced form (according to the Waste Act § 66 psg. 1^1), where the municipality takes over the customer service, involving separation of the waste collection and treatment services, setting high demands on the waste collection service quality, and integrating some public waste management services into OWCS, even more economic, environmental and social benefits can be achieved through the OWCS. Thus, the OWCS comprises an effective administrative tool in itself in order to optimise the environmental and economic impacts and feasibility of a waste management model.

The waste management environmental and economic impacts have been assessed from the aspects of waste treatment options (Voronova, 2013 and Moora, 2009) but the administrative efficiency, and the possibilities to reduce the environmental and economic load of the waste management through the administrative reorganisation have not been examined thoroughly in Estonia. The research and methodology of the current thesis involve analysis of the input data and modelling of the environmental and economic impacts involving treatment specification, transportation and characteristics of the collection area from which the conclusions for the best collection and treatment schemes are drawn. The expected results of the thesis should reveal the optimal administrative waste management model for a rural municipality, including the organisational manual such as description of the municipal tasks in waste management, requirements, conditions and tender specifications for the organised waste collection public procurement, and equation for the formation of the waste collection fee (**Papers III** and **V** added to the thesis).

An analytical excel based tool for the local authorities in order to evaluate the economic and environmental performance of the current and planned waste management model was compiled as the empirical part of the thesis research. The main innovation and benefit of the tool stands in the availability and simplicity of the input data. Relying on the personal work experience as the consultant for the Estonian local authorities, the author is acquainted to the difficulties how and where from to retrieve the detailed and adequate data about waste composition, source sorting rates, treatment operations etc. necessary to feed an LCA model. The invented tool requires only data which is available in the public databases and registers or any databases held by the municipality. Thus the tool is usable for any local authority in Estonia, and presumably in any European country as well.

The research of the thesis was carried through within two projects: the project No. SFE25 “Sustainable utilisation of waste and industrial non-core material” (hereafter SUSBIO project), 01/05/2010–30/08/2013, granted by the Central Baltic INTERREG IV A-Programme, Southern Finland – Estonia Sub-programme; and the project No. 1.5.0303.11-0359 “Development of waste management cooperation in Harju County Municipalities” (hereafter Harju WMC project), 01/08/2011–30/06/2012, granted by the European Structural Assistance to Estonia through the Ministry of Finance of the Republic of Estonia priority 1.5 “Administrative efficiency” programme “Training and development of employees of the State, local authorities and NGOs” sub-programme “Organisational development”.

The objectives of the SUSBIO project were to screen commercially available quantities and the qualities of the non-core materials of the food value chain players and the agricultural and municipal bio-waste in major urban areas of Southern Finland and Estonia, to evaluate the impact of the bio-component separation and biofuel production on the sustainability of the whole value chain, and to compare the common practise today (SUSBIO, 2013). The project partners were Turku University of Applied Sciences, Tallinn University of Technology and Tallinn City Government. The project proved that the total environmental load can be reduced in the Baltic Rim and both sustainability and economics can be improved in the value chain by better material efficiency and proper handling of the waste. The biodegradable waste management options including biogas production and biogas collection from a closed-down landfill are analysed in the **Papers I** and **IV** included to the thesis.

The aim of the Harju WMC project was to rise the administrative efficiency in Harju County municipalities, to improve the cooperation in waste management sector, and to provide high-quality municipal waste collection services according to the principles of sustainable development in the county (HOL, 2012). The project partners were the members of the Union of Harju County Municipalities (HOL), meaning all the Harju County municipalities. The executive manager of the project was WasteBrokers LLC (Jäätmemaaklerid OÜ) with its waste experts including the author of the current thesis. In response to the results of the project, the Communal Services Centre of Harju County (MTÜ 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 (Paper II). The options to reduce the environmental and economic impact of the waste management through the administrative tool such as the OWCS by optimisation of the waste collection routes and implementation of source sorting, and also by reorganisation of the waste management administration are analysed in the **Papers II, III** and **VI** included to the thesis. The legislative background, main principles and conditions of the OWCS are introduced in the **Paper II**, and the socio-economic benefits arising from the implementation of the advanced OWCS are analysed in the **Papers III** and **VI**.

The financial aspects of waste collection service are more thoroughly and in details analysed in the **Papers V** and **VI**. The **Paper V** is focused on the formation of the waste collection fees at the OWCS public procurements, and in the **Paper VI** the economic and environmental feasibility of source sorting of bio-waste and paper is estimated. In the **Paper VI** the re-municipalisation and inter-municipal cooperation is also analysed. The **Paper VI** aims to optimise the rural waste management model especially through the inter-municipal cooperation. Re-municipalisation of the communal services is a recent trend in Europe (Hall, 2012) and recent empirical research has confirmed that, contrary to common assumptions that private sector performs more efficiently, there are no significant differences in efficiency between public and private waste operators if the competition between service operators is maintained (Bel, Fageda and Warnerd, 2009). Moreover, a municipal organisation is generally a non-profit one, which rather aims to improve the quality of the public services than focusing on raising the gross margin. Same time all the services (both main and supportive such as either waste collection or logistics or customer service or accountancy) provided by the municipal organisation are procured from private enterprises which in turn puts their gross margin under pressure. Thus the outcome may as well be the cheapest on the market. In the Harju WMC project the cooperation model involved municipalisation of only customer service and accounting part of the OWCS, while the waste collection and waste treatment services were to be outsourced as the results of public procurements, which is open competition.

The author declares that the research contributes to her current occupation professionally, and aims to solve the main problems in the municipal waste management in Estonia, including the bio-waste collection and treatment. The results of the research can be applied to any rural municipalities or areas with potential for administrative cooperation between neighbouring municipalities.

2 AIM OF THE THESIS

The aim of the thesis was

- to draw environmentally and economically optimal municipal waste collection and treatment scheme for the municipalities with low population density, where the rural areas are prevailing,
- to analyse the environmental and economic efficiency of source sorting and central collection of paper and bio-waste, and review their treatment alternatives
- to assess the possible improvement of administrative and financial efficiency of waste management arising from inter-municipal cooperation in rural municipalities by case of Harju County municipalities in Estonia.

Research design

In order to meet the objectives of the thesis the research was carried out in the following stages:

- Collecting data on bio-waste amounts within the SUSBIO project (**Papers II** and **IV)**
- Analysing biogas production options from source separated bio-waste within the SUSBIO project (**Paper IV)**
- Reviewing the waste management legislation (**Papers II, III** and **V)**
- Mapping of the waste management situation in Harju County municipalities within the Harju WMC project (**Papers II** and **III)**
- Analysing OWCS service, service fees, service volume within the Harju WMC project (**Papers III** and **VI)**
- Analysing OWSC procurement models, compiling of the new model within the Harju WMC project (**Paper III** and **V)**
- Compiling of the excel based tool basing on above-mentioned activities and other research results (the Thesis)
- Testing the tool, formalising the results (the Thesis)

Methodology

The research methodology of the current thesis involves some standard methods (SWOT, Monte Carlo, Cost-Benefit Analysis) which are applied in the different stages of the research. The reason why LCA was not applied stands in the limits of available input data. An LCA model requires a wide range of precise and good quality input data in order to generate adequate results. Since not all the required data were available in sufficient amounts and quality, the author of the current thesis decided not to apply LCA, but exploit other suitable methods dependent on the particular stage of the research.

The Tool and evaluation models for the OWCS public procurement, which are both Excel based systems, are the methodologies invented by the author of the current thesis.

The following methods were applied in the different stages of the work:

- Environmental monitoring of a closed-down landfill – Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (**Paper I**)
- The feasibility analysis of the Harju County WMC – EC methodology for Cost–Benefit Analysis of Investment Projects (EC, 2008b; Järve 2012 and **Papers II** and **III**)
- Risk and sensibility analysis – Monte Carlo analysis (Järve, 2012 and **Paper III**)
- Bio-waste utilisation – SWOT analysis (**Paper IV**)
- OWCS procurement tender evaluation model – worked out by the author (**Paper V**)
- Evaluation of the OWCS service volume and turnover basing on the data of the WHRs and currents OWCS service fees filed by the author – Excel based modelling worked out by the author (**Paper VI**, thesis)
- The evaluation tool to measure the waste management performance of the local authority – Excel-based modelling worked out by the author (Thesis)

3 WASTE MANAGEMENT BACKGROUND

The general input data of the current research were the number of population (KOP, 2014), size of the territories (KOP, 2011), calculated population density, waste generation of mixed municipal waste (MMW), separately collected paper and cardboard (PC), and bio-waste (BW) (EEIC, 2012), structure of dwellings (BSE, 2011), waste management budgets (MFER, 2012), structure of roads (Teeregister, 2012), OWCS contracts validity and contracting parties, number, sizes and emptying intervals of the waste containers (data of waste holders' registers, WHR), and the waste collection fees of MMW, PC and BW. The waste management situation in Harju County municipalities, including the main problems regarding waste management, municipalities budgets and public utilities, source sorting options, status of legislation, validity of the OWCS contracts and contracting parties, waste collection service fees, and databases of the WHRs, was filed by the author in 2011-2012 within the Harju WMC project using questionnaires and interviews addressed to the waste management officials of the Harju County municipalities, homepages of the municipalities and waste companies, and official database of the waste management permits (http://klis2.envir.ee). The file has been periodically updated by the author, last in April 2014.

A detailed survey about the waste management situation in the Estonian municipalities was carried out by the Estonian Ministry of the Environment in 2013. The questionnaire involved questions about implementation of the OWCS, source sorting and the delivery options for the source sorted waste, waste stations and composting options, waste management budget and cooperation with the other municipalities (EMEDW, 2013).

3.1 Demographical, territorial and infrastructural background

The population density in Estonia is illustrated on the Figure 1.

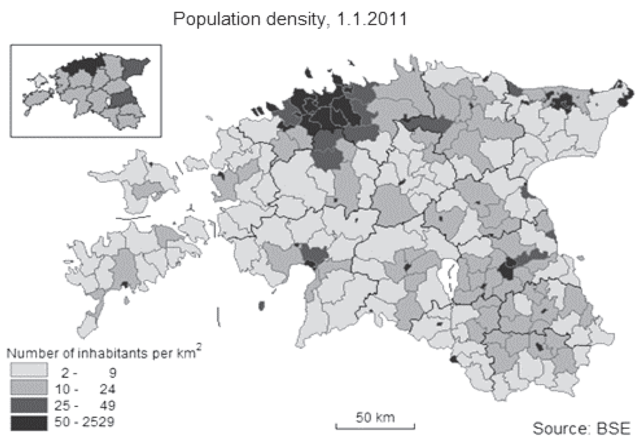

Figure 1. The population density of Estonia (BSE, 2014a)

As mentioned in the section "Introduction", the demographical background like the number of inhabitants and population density are important indicators when planning the municipal waste collection schemes. Regarding source sorting of BW and PC the structure of dwellings is another key indicator. In the current research, also the length of roads and streets within the municipality (means distance between the waste generation sites) was used. Below the number of inhabitants (KOP, 2014), sizes of the administrative territories (KOP, 2011), calculated population densities of the Harju County municipalities, structure of dwellings (BSE, 2011), and length of roads (Teeregister, 2012) are presented in the Table 1.

Table 1. Demographical, territorial and infrastructural background of the Harju County municipalities

2014	population	territory km^2	inh/km^2	buildings with 10+ dwellings	roads and streets km
Aegviidu parish	747	12.0	62.4	5	24.3
Anija parish	5,752	520.9	11.0	45	161.7
Harku parish	13,021	159.1	81.9	63	102.7
Jõelähtme parish	6,128	210.9	29.1	34	191.5
Keila parish	4,736	178.9	26.5	34	294.9
Keila town	9,747	11.3	866.2	90	49.0
Kernu parish	2,022	174.7	11.6	12	268.6
Kiili parish	4,587	100.4	45.7	9	102.5
Kose parish	5,725	237.3	24.1	48	113.7
Kuusalu parish	6,631	707.9	9.4	50	311.3
Kõue parish*	1,644	295.5	5.6	10	83.5
Loksa town	2,809	3.8	738.0	35	20.5
Maardu town	15,945	22.8	700.4	120	107.0
Nissi parish	2,948	264.9	11.1	28	188.0
Padise parish	1,750	366.6	4.8	11	303.8
Paldiski town	4,067	60.2	67.6	38	111.3
Raasiku parish	4,693	158.9	29.5	24	184.5
Rae parish	14,287	206.7	69.1	131	121.0
Saku parish	9,202	171.1	53.8	58	97.4
Saue parish	9,897	195.2	50.7	80	104.3
Saue town	5,924	4.4	1 350.4	34	30.8
Vasalemma	2,599	38.7	67.2	28	48.5
Viimsi parish	17,929	72.8	246.1	79	209.4
Harju County, excl. Tall.	152,790	4,175	36.6	1,066	3,230.2
Tallinn City	429,829	158.3	2,715.8	3,550	954.0
TOTAL	582,619	4,333	134.5	4,616	4,184.3

* *Joined Kose parish 1.1.2014*

Here and hereafter in any calculations which consider the number of inhabitants, the data of the relevant year is taken into account, e.g. if the annual waste management budget in 2010 or 2012 is calculated per capita, then the number of inhabitants in the years 2010 or 2012 accordingly is considered.

3.2 Municipal waste generation and composition

The municipal waste generation in Estonia has gone through some tides within last decade, following the curves of economic growth and decline, reaching its peak in the middle of 2000. Since then a clear trend can be detected, which is the increase in amounts of source separated waste such as bio-waste, paper and packaging waste, and recovery of those waste classes. The official database of waste statistics (EEIC) enables queries by year, waste class, municipality and treatment operation from the year 2004 when Estonia adopted the European classification of waste treatment operations and waste classes by implying two main legislative acts in waste management, the national Waste Act (EP, 2004a), and the List of wastes, including hazardous wastes (EP, 2004b). Figure 2 gives the overview about the generation of mixed municipal waste (MMW) with code 20 03 01, and source separated organic kitchen waste (bio-waste, BW) with code 20 01 08, paper and cardboard (PC) with code 20 01 01 and general packaging waste (PW) with code 15 01 (EC, 2000 and EP, 2004b) in Estonia.

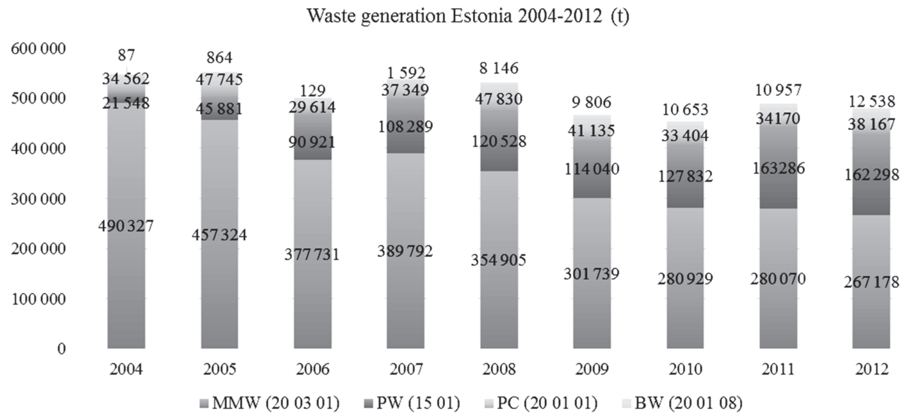

Figure 2. Waste generation in Estonia 2002-2012

Although source sorting of BW and PC is compulsory in many municipalities and central collection of source sorted BW and PC is involved to the OWCS, the MMW still contains a considerable amount of biodegradable fraction. The composition of MMW in different types of settlement in Estonia has been analysed in two researches in 2008 and 2013 (Moora, 2008; Moora, 2013). Regarding these analysis, the average content of biodegradable fraction (including PC) in the MMW in Estonia was approximately 45% in 2013, and within previous 5 years it had decreased about 16%. According to Moora (2013) the Estonian average MMW consists of 31.8% of BW (Table 2).

Table 2. The percentage of biodegradable fraction in MMW, 2008 and 2013

Biodegradable fraction, % in MMW	2008		2013		Change in %	
	Rapla County	Estonia, avg.	Järva County	Estonia, avg.	Counties	Estonia, avg.
Bio-waste, including:	36.99	36.65	31.10	31.80	-15.92	-13.23
kitchen waste	*32.11*	*30.00*	*27.50*	*26.90*	*-14.36*	*-10.33*
green waste	*3.48*	*5.27*	*2.90*	*3.80*	*-16.67*	*-27.89*
other bio-waste	*1.40*	*1.38*	*0.80*	*1.10*	*-42.86*	*-20.29*
Paper and cardboard	16.27	17.53	12.60	13.50	-22.56	-22.99
TOTAL	53.26	54.18	43.7	45.3	-17.95	-16.39

3.3 Municipal waste treatment options in Estonia

The waste treatment market in Estonia has gone through two main trends within the last decade. First trend, from landfilling to recovery and recycling (Fig. 3), has shifted the waste treatment facilities further from waste generation sites, which has direct influence on the waste transportation costs. The other trend, from mixing to sorting (Fig. 2), however has brought the primary sorting centres closer to waste holder, which has also kind of impact on waste transportation.

3.3.1. Landfills

Since 2009, there are 5 regional non-hazardous waste landfills in Estonia which fulfil the requirements of EU Landfill Directive: Jõelähtme, Paikuse, Torma, Uikala and Väätsa (EEIC, 2014). Till the mid 1990ties there was a landfill next to every bigger settlement, and most of these landfills did not meet any environmental criteria nor had any monitoring or supervisory. From 2001 all the 350 landfills, which did not fulfil the requirements of the EU Landfill Directive (EC, 1999), have been closed down, last of them just before the 16^{th} of July 2009 (EME, 2009). Today all the five regional landfills comprise the recycling facilities beside the landfilling operation. The Jõelähtme landfill, with the new name Tallinn Recycling Centre (TRC) was opened in 2003 and has the MBT, composting and sorting sections on its territory (TRC, 2014). Under the name Paikre the landfill and sorting station are working (Paikre, 2014). In Torma landfill there are also a composting field and sorting area (Torma Prügila, 2014). However, the environmental impact assessment of the close-down of this landfill has been initiated (Keskkonnaamet, 2013). At the Uikala landfill beside sorting and composting RDF is produced (Uikala Prügila, 2014). At the Väätsa landfill there is also a sorting facility for the packaging waste and a composting field (Väätsa Prügila, 2014).

3.3.2. Recovery

There are 3 MBT plants in Estonia. In May, 2011 TRC opened in its territory an RDF production facility with the annual capacity of 120,000 tons of MSW. The launched facility uses the MBT technology. By opening the RDF plant, TRC aims to reduce the proportion of disposal lower than 20% in its activities (TRC, 2014). In October, 2011 Ragn-Sells Ltd opened an MBT plant which is unique and most modern in the Baltics and North Europe. The facility with its annual capacity of 120,000 tons aims to direct 85% of the input MSW to the recycling (Ragn-Sells, 2011). Since 2008, a smaller MBT terminal has been working on the territory of Uikala landfill, in which within last 5 years 2,500 tons of RDF has been produced from 45,000 tons of MSW (Ecocleaner, 2014). From June 2013 also mass incineration of MSW is available in Estonia. At the Iru CHP Station the MSW mass incineration unit was developed with the annual capacity of 220,000 tons (EE, 2013). As we see from above, the annual capacity of recovery operations (incineration + MBT, approximately 470,000 tons) exceeds the generation of MMW almost twice.

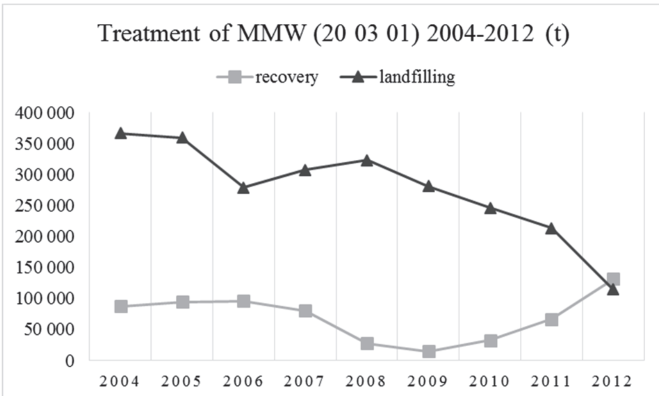

Figure 3. Recovery and landfilling of MMW in Estonia 2004-2012 (EEIC, 2012)

As revealed from the Fig. 3, landfilling of MMW has steadily decreased and year by year replaced by recovery operations. The decrease in recovery in years 2008-2010 is due to the lack of operators. The Tallinn Waste Sorting Plant closed the gates in 2007, having been sorted around 90,000 tons of MMW each year which was declared as recovery operation. As 2011 two MBT facilities were launched, the recovery of MMW has increased, and since 2013 majority of the MMW should go through the recovery operations due to the Iru incineration plant.

3.3.3. Biological treatment

According to the survey carried out by the Estonian Ministry of the Environment amongst Estonian local authorities, most of the local composting facilities are either at the wastewater treatment facilities where sludge is processed with a marginal amount of gardening waste, or facile open windrow composting sites for gardening waste. Technologically equipped composting facilities, where biodegradable kitchen waste can also be processed are only at the regional landfills or few waste stations (EMEDW, 2013). In addition, there are four biogas stations in Estonia (Vinni, Aravete, Jööri, Oisu) which would offer an alternative treatment option for the organic kitchen waste (EBP, 2014). These biogas stations are currently oriented on the biogas production from manure. The biogas production units at some wastewater treatment plants (Tallinn-Paljassaare, Tartu) could also offer an alternative treatment option for the organic kitchen waste, however these facilities require the feedstock of very high quality.

3.3.4 Sorting

As far as known to the author, most of the municipal waste collection and treatment companies have smaller or bigger sorting plants for paper and packaging waste at their depots. As the primary collection options, there are more than 5,000 packaging containers (Kaukvere, 2013) and about 100 public waste stations (EMEDW, 2013) all over Estonia. In addition, there are numerous collection points for domestic hazardous waste provided by municipalities and collection points for WEEE provided by producer responsibility organisations.

3.4. Municipal waste collection and source sorting

3.4.1 Source sorting

Source sorting is one of the base responsibilities of any waste holder in Estonia. Relaying on the Waste Act, the municipalities have imposed in the local waste regulation the particular waste classes must be sorted out and not discarded within the MMW. In the observed region, Harju County, in most of the municipalities the source separation of some waste classes from the MMW is compulsory. These waste classes are usually domestic hazardous waste, WEEE, PW, PC and in many municipalities also BW. As to the WEEE and PW, the collection containers are provided by the producer responsibility or recycling organisations in accordance with the producer responsibility principle arising from Waste Framework Directive, Packaging Act and Waste Act, thus WEEE and PW are not the subjects of the current research. Domestic hazardous waste collection and treatment is service provided by municipalities on the account of their budget, and the costs of the service are included to the financial analysis of the thesis.

In the municipalities where separate collection of PC and BW is compulsory, the central collection of these waste classes is applied in the apartment houses with generally more than 10 apartments. Rest of the households are suggested to deliver PC to the public containers or waste stations, and compost BW on site. According to the local waste regulations and data of the WHRs, the frequency of bio-waste collection is generally once per week. This requirement is applied in consideration of environmental and health protection aspects. If the bio-waste container is emptied at longer interval, the biodegradation processes are launched in the improper conditions, which may result in spread of smell, pathogens etc. The minimum collection frequency of paper waste is generally fortnightly or once a month (28 days), in some cases even quarterly (84 days). The environmental and economic feasibility of the central collection of source separated PC and BW is in focus in the current thesis.

The decision whether a selective collection system should be introduced and the choice of the best system are crucial questions public authorities must answer. It is up to Member States to determine whether separate collection of bio-waste is appropriate. This depends inter alia on adaptation of the collection schemes to the local context where population density is an important element since source-separated collection can be difficult to implement in highly-populated areas, i.e., due to insufficient space for storage of several waste streams inside home sorting as underlined in the annex of the COM(2010)23528 may be ineffective, leading to lower amount and lower purity of the targeted selective stream; and in very rural areas, i.e., great distances covered per amount collected (however, this plays a limited role in the overall impact) (Manfredi and Pant, 2011).

3.4.2 Implementation of the OWCS

Implementation of the OWCS, involved waste classes, and validity of the OWC contracts in the Harju County municipalities is presented on the Fig 4.

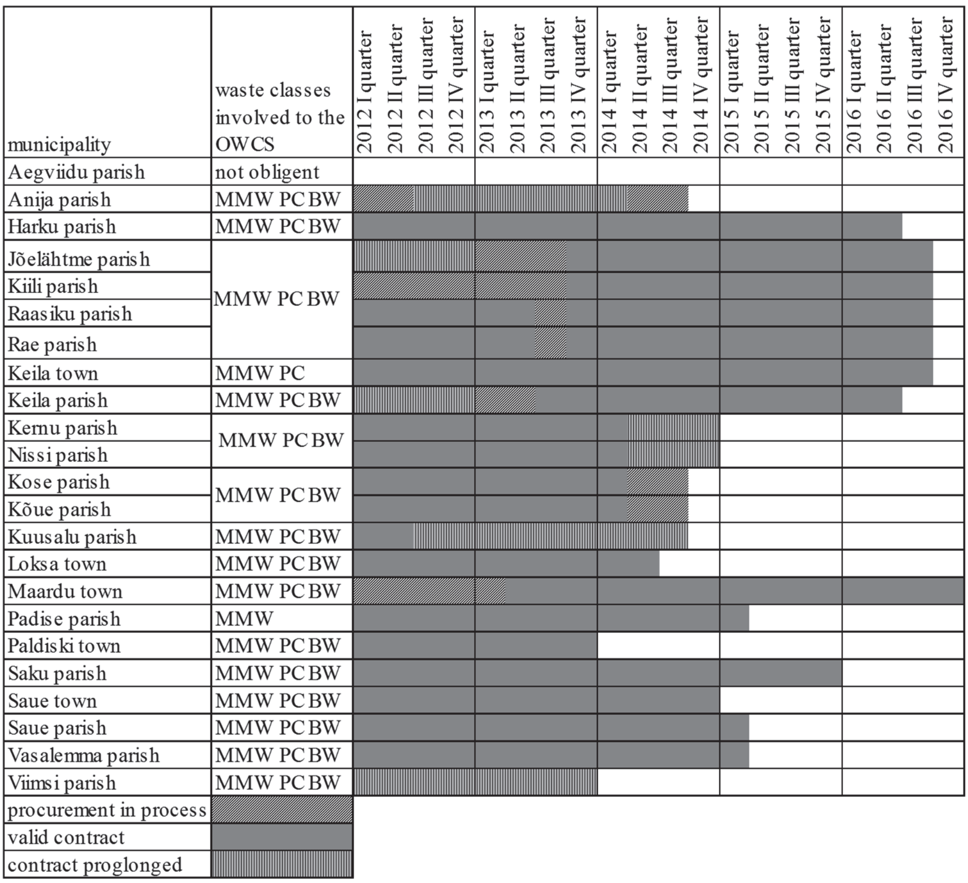

Figure 4. Implementation of the OWCS in Harju County municipalities

As defined in the Waste Act, the organised waste collection scheme (OWCS) 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. The local authority holds a concession of services procurement to select the waste collection service provider, and determines the waste treatment facility. The OWCS involves the mixed municipal waste, and the source sorted waste (EP, 2004a).

The main principles of OWCS are outlined in the Waste Act, as follows:

- the territory of a local authority is divided into waste collection districts involving usually no more than 30,000 inhabitants;
- the licence to provide the waste collection service in the district is granted for up to five years;
- the waste holders are obliged to join the waste collection system;
- exemptions from that obligation are justified only by the reason that a house or real estate is not actively used in any way that would result in waste;
- waste company provides the municipality with data regarding waste holders and updates the WHR, thereby providing frequent up-to-date feedback about incorporated and unincorporated waste holders to the local authority.

In the advanced OWCS the municipality holds separate public procurements for waste collection, and waste treatment services. This model enables to integrate some waste management costs (e.g. WHR, domestic hazardous waste collection, advising and awareness raising activities) into waste collection fee as the administrative costs, which disencumbers the municipality's budget from those expenses, and mitigates the lack of funds for public waste management services by directly applying the polluter-pays principle.

The main objectives of OWCS are to incorporate all the households and waste holders into the waste collection system, to control the waste collection fee and service quality, to minimise the environmental impact of waste collection and, last but not least, to develop source sorting. In most of the Estonian municipalities the OWCS has been implemented, and in urban areas in addition to mixed municipal waste mostly source sorted PC and BW are also involved to the OWCS.

The conditions of the OWC contracts may vary at a large scale from municipality to municipality from detailed description of the waste collection service, and from strict technical requirements to a very general conditions such as that the municipal waste must be collected from households and treated somewhere. The impact of impact of tender specifications and evaluation model of the waste collection procurement on the waste collection fees and OWCS service quality is discussed in the **Paper V** added to the thesis.

3.5 Waste management tasks of the municipalities

According to the Waste act, a local authority is responsible for the development of the waste management, including awareness raising activities (§ 12), compilation of the local waste management action plan (WMAP) (§ 42) and local waste regulation (§ 71), organising the source sorting and recovery of the source sorted waste (§ 31), managing the domestic hazardous waste (§ 65), organising the OWCS (§ 66…70), including selection of the waste collection company (§ 67), incorporation of the waste holders to the OWCS (§ 69) and organising the treatment of the waste classes involved to the OWCS (§ 70), keeping the WHR (§ 71^1), and executing the supervisory (§ 119) (EP, 2004a). Except the enforcement of the legislative acts (WMAP and waste regulation) which is the jurisdiction of the city or parish council, and execution of supervisory, the rest of the waste management duties can be delegated from the local authority to a non-profit organisation which belongs to the local authority or authorities in accordance with the Administrative Co-operation Act. This covers also the drafting of WMAP, waste regulation and OWCS procurement documentation, which relying on the practice of the author, is a service widely outsourced to consulting firms due to the reasons mentioned in the section 3.6 regarding multiplicity of the tasks and level of competence.

3.6 Waste management cooperation in Estonia

All in all, inter-governmental cooperation involving municipalities is a phenomenon that can be found in all Western European countries. In some it has a long history, in others it is relatively recent; it varies in presence, weight and form, but it is never completely absent (Hulst and van Montfort, 2007).

There are 7 regional cooperation organisations (KEJHK, IEJHK, RJKK, VPKK, Hiiumaa County Council, HÜK, LVOL), and few other cooperation attempts directly between some municipalities to form inter-municipal waste collection districts, comprising altogether approximately 300,000 inhabitants in about 30 waste collection districts from about 100 municipalities. The cooperation involves only some of the tasks listed in section 3.5 (usually the OWCS related tasks, and drafting the WMAP and waste regulation), although there is potential for more cooperation and competence. A waste management centre (WMC) could also take over the administration and running of the public waste stations and collection points, waste awareness raising campaigns, keeping the WHR, and organise the collection and treatment of domestic hazardous waste collection within the OWCS. As to the cooperation on OWCS, the inter-municipal waste collection districts still comprise averagely about 10,000 inhabitants which is far less than indicated in the Waste Act.

Another strong argument for the inter-municipal cooperation, beside optimisation of the waste collection logistics, is improvement of the administrative efficiency. In each of the Harju County municipalities (and in the rest of the Estonian rural municipalities) there is at least one official who is in charge of the waste management tasks mentioned above. In addition, and dependant on the size and administrative structure of particular municipality, more officials, a head of division, and members of parish government are involved not only to the decision making process but in several cases also to the practical tasks. Usually same officials are in charge of some other public services as well, since a rural municipality cannot afford hiring a particular specialist to each public service but the services are grouped by general topics (like environmental issues, engineering, social services etc.) and shared between couple of specialists. In Harju County, this makes 23 administrative units which struggle the same problem – multiplicity of the administrative tasks of the officials who cannot specialise on one particular task, and therefore cannot develop sufficient competence in all the fields or public services.

Sharing the administrative tasks between a bunch of municipalities already would increase both the administrative efficiency and level of competence as well. If a regional WMC would take over the waste management tasks from the municipalities, only few specialists could fulfil same amount of tasks. Basing on the work experience in Tallinn Environment Department, one full-time specialist (including part-time work-loads of the officials in city district councils) per 40,000 inhabitants is enough to execute the all OWCS related tasks, plus few more officials to fulfil the other waste management tasks (administration of the waste stations and public containers, supervisory, WHR, awareness raising activities, waste management permissions, planning and developing waste management) per whole city. Thus, even if there were 15 full-time work-loads per 420,000 to fulfil all the waste management tasks, roughly one specialist per 25,000 is enough for one waste management task. Since there are 4-5 main general task which need specialisation – 1) planning, development, legislative and awareness raising activities; 2) management of public waste stations and collection points, including hazardous waste collection; 3) OWCS related tasks like running public procurements, supervisory over contractor, dealing with exclusions from OWCS; 4) keeping WHR; and 5) executing general supervisory – an optimal number of inhabitants for a regional WMC were 100,000-125,000.

Bel and Mur (2009) analysed the effects of inter-municipal cooperation and privatisation on the delivery costs of urban solid waste services in rural environments. Regarding the two original variables in their work, they found that a greater degree of dispersion within a municipal area affects total costs positively, as the complexity of the service was necessarily increased. At the same time, the "inter-municipal cooperation" variable led to a reduction in costs in municipalities with smaller populations; that was, small municipalities providing the service as an association incurred lower service costs (Bel and Mur, 2009).

Sustainability and territorial cohesion can be achieved effectively by metropolitan (functional) areas and urban-rural cooperation. Areas that surround cities contribute to sustainable economic development, energy supplies and the overall quality of life. They give access to a wide range of resources, including local food production and recreational facilities. Similarly, hub cities are often the main attraction for investment and visitors, as well as centres of commerce, education, culture and jobs, providing facilities such as hospitals, waste and water management and connections to major transport systems. Urban and rural areas must – and many already do – cooperate to contribute to a balanced territorial development (EUROCITIES, 2012).

Inter-municipal cooperation on one hand creates some form of institutionalised governance to address the issues of scale and rising market pressures on local government. It aspires to provide for public service delivery that meets the rising demands of citizens of the local communities at the lowest costs possible; it seeks to regulate the externalities of local policies to prevent the waste of public resources and to strengthen the capacity of joint municipalities to cope with the opportunities and threats of an increasingly complex and dynamic environment. On the other hand, inter-municipal cooperation leaves the policy domain of local government intact. Irrespective of the form it takes, there is no permanent transfer or loss of local tasks or competencies and somehow local governments keep control over the decisions and services that result from cooperation (Hulst and van Montfort, 2007).

3.7 Environmental and socio-economic aspects of waste management

3.7.1 Environmental impact of waste management

Abeliotis (2011) presents the main environmental impacts of waste management from the aspect of the life cycle assessment (LCA). LCA assesses the use of resources and the release of emissions to air, water, land and the generation of useful products. All these inputs (material and energy resources) and outputs (emissions and products) have to be identified and quantified during the life cycle inventory (LCI) phase of the LCA. The main components of the waste management environmental impact are collection and transportation of waste, and waste treatment including different operations. For the compilation of an effective LCI in the collection and transportation stages of an LCA, Abeliotis mentions inter alia collection frequency, distance covered, type of collection truck and fuel, and density of the waste fractions in containers and collection trucks as the inevitable parameters to take into account. The main components of the environmental impact of the treatment operations are material and energy input, and output as different emissions (leachate, gas, smell), solid residues and energy (Abeliotis, 2011).

In the current thesis, the environmental impact of waste collection and treatment is assessed in only the emissions in CO_2 equivalent arising from transportation (fuel burning) and different treatment operations (landfilling, incineration, anaerobic digestion, aerobic and home composting, recycling). The reason for leaving aside the type of containers, trucks and fuel, in other words, the material input, was to maintain the simplicity of the tool so that a local authority would be capable of using it. The other indicators were left aside also in consideration of ceteris paribus principle. The bulk density of waste and collection frequency were applied as constants derived from other researches and databases of WHRs respectively.

3.7.2 Socio-economic aspects of waste management

Morrissey and Browne (2004) proposed that a sustainable waste management model should not be only environmentally effective and economically affordable but also socially acceptable. The socio-economic aspects of waste management are described in **Papers II** and **III** added to the thesis. The range of socio-economic aspects varies from the individual environmental awareness and conscience of a waste holder to national waste management funding principles, including environmental taxation. In Estonia, the public waste management services are financed from the budget of local authority, which is filled from two sources: personal income taxes, and re-dealing of environmental charges through different national programmes and funds.

Relying on the personal experience in implementation of the OWCS in Tallinn City first waste collection districts in 2006, the author declares that the social acceptance of the new waste collection system relied on two main components: the notification in advance, and the price of the service. Although the main counter-argument from the waste holders' side was that they do not accept a waste company selected by the city, after few month from implementation of the OWCS when the service run smoothly, the social acceptance was attained. The OWCS offers more benefits than the free market waste collection especially from the socio-economic aspects: the quality of the service is assured by the municipality, the service fee is usually cheaper and fixed for the long period, and service provider is not free to raise the fee as wanted, there is only one service provider in the waste collection district, thus all the waste holders are the clients of one firm who is responsible for the whole district, the logistics of waste collection is optimised, and the availability of the service for a reasonable price is granted everywhere, which is especially important in the rural areas and areas of detached houses.

The other socio-economic aspects regarding waste management as a public service are implementation of source sorting, network or availability of public waste stations and collection points, which also rely on the two abovementioned components – notification of the waste holders and the public awareness, and price of the service. Both of the components depend directly on the administrative competence and financial capability of the municipality. Therefrom the dilemma of the waste management funding principles arises. Since most of the public waste management services are financed from the general budget of municipality, it cannot be considered to be directly in accordance with the polluter-pays principle. Yet, the public waste management services tend to be that kind of services which in case of being fairly priced, would not be used either, e.g. if the domestic hazardous waste collection service were priced, the majority of the domestic hazardous waste ended up in the MMW container. The current thesis aims to solve also the funding issues of the public waste management services in accordance with the polluter-pays principle.

Lohri et al. (2014) emphasis that a more detailed cost structure and cost-revenue analysis of waste management service is important with appropriate measures, either by the private sector itself or with the support of the local authorities, in order to enhance cost efficiency and balance the cost-revenues towards cost recovery. They present four options on how financial sustainability of the solid waste management system might be enhanced: (i) improved fee collection efficiency by linking the fees of solid waste collection to water supply; (ii) increasing the value chain by sales of organic waste recycling products; (iii) diversifying revenue streams and financing mechanisms (polluter-pays-, cross-subsidy- and business-principles); and (iv) cost reduction and improved cost-effectiveness (Lohri et al., 2014).

There have been several strikes and disputes in the refuse collection and waste management sectors in Europe in the last years. Some have arisen from general restructuring of payment systems, but most are caused by low pay and unhealthy working conditions, or by contractors withholding wages (Hall, 2010). Most unions of public service workers favour public ownership in preference to privatisation. Public sector employees generally feel more secure than private sector workers, because private companies have incentives to cut jobs or pay in order to increase profits, they may decide to close down less profitable operations, and they may go bankrupt (Hall, 2012).

There is also evidence that it matters to the public, who have greater confidence in the public sector, even in incineration which is often controversial due to its environmental impact. Much of the recent re-municipalisation in Germany is supported by a generally higher public trust in municipal operators (Hall and Nguyen, 2012). The most important factor in all the re-municipalisations has been the reduction in costs and greater efficiency of an in-house service the opposite of what the private sector claims. Municipalities in the UK, Germany and Finland all say that efficiency and cost issues are the most important factors. Some services require a lot of investment, and public authorities can nearly always borrow money at lower interest rates than private companies (Hall, 2012).

3.7.3 Re-municipalisation of the waste management services

Empirical evidence now strongly supports the view that the private sector is not generally more efficient than the public sector, in waste management as in other sectors. (Hall and Nguyen, 2012). After many years when privatisation, contracting-out and outsourcing have been the dominant trends across the public services in Europe, there is now increasing evidence, particularly in the municipal sector including water and energy of trends in the opposite direction (Hall, 2012). In Germany, there was a slight net re-municipalisation between 2004 and 2007. The key factors included improving the quality of service, greater control over policy, desire to avoid oligopolies, and social concerns for the workers' pay and conditions. There was still a tendency to re-municipalisation in 2011 (Hall and Nguyen, 2012).

In Estonia, similar trend can be detected in the waste management sector. Since 2009 Tallinn City has prepared to take over the customer service of OWCS in accordance with the Waste Act § 66 psg. 1^1 (author's work experience in Tallinn Environment Department), and now also considering buying out the 65% share of Veolia in the TRC (Krjukov, 2014). Since 2013 Tallinn Waste Centre, a sub-division of the Tallinn Environment Department has provided the advanced OWCS for the pilot city district Põhja-Tallinn (North-Tallinn), and is planning to take over the OWCS customer service in next city districts one after another (TED, 2013), (TWC, 2014), (Masing, 2013).

Re-municipalisation of the OWCS service is limited with the Waste Act § 66 psg. 1^1, and § 1 psg. 5, according to which the § 14^1 of the Public Procurement Act may not be applied on the OWCS (EP, 2004a). The § 14^1 of the Public Procurement Act regulates the in-house transactions (EP, 2007). This means, that the waste collection service must in any case be procured by the municipality or the authorised non-profit organisation owned by the municipality, and even if the municipality had a waste collection company, the only entrance to the OWCS market to it were through the fair competition with other waste collection companies on the OWCS public procurement held by that municipality.

Most re-municipalisations in a number of countries in Europe have taken place when an existing contract or concession with a private company expires. Failures and problems with private sector performance are key reasons for re-municipalisation (Hall. 2012). The impact of EU environmental legislation on the waste sector in member states has been to require higher investment and greater activity in collecting, processing and treating waste. It has improved public services and overall increased employment in this sector. There is no sector-specific legislation requiring increased privatisation, liberalisation, or competitive tendering. However, the growth in the sector has increased business interest, the greater use of incineration has led to a growth in PPPs – often linked to privatisation of "feeder" refuse collection contracts, and the interpretation of EU procurement and internal market laws has put pressure on municipalities to open more work to tenders from the private sector (Hall et al., 2011).

4 MATERIALS AND METHODS

4.1 Description of the tool

As the empirical part of the thesis research, an excel-based tool for local authorities was invented (hereafter the Tool). The aim of the Tool is to measure the economic and environmental performance of the current waste management system, and offer alternative scenarios. The Tool has a complex approach on the waste collection service volumes, source sorting of bio-waste and paper, OWCS public procurement tender evaluation models, administrative efficiency, and environmental impact of the waste management model. The project scenarios are described in the **Papers II** and **III** added to the thesis. The formation of the OWCS service fees are introduced in the **Paper V** added to the thesis. The cost-benefit analysis is carried out in the **Papers II** and **III** added to the thesis.

In the work-out and testing phase 4 imaginary municipalities (M1, M2, M3, M4) were used with similar profiles to some Harju County municipalities (Table 3).

Table 3. General data of the municipalities

General data	**District**	M 1	M2	M3	M4
Population, inh.	25 500	8 200	11 300	4 900	1 100
Territory, km^2	325	40	75	120	90
Population density, inh/km^2	78,5	205,0	150,7	40,8	12,2
Number of buildings with 50+ dwellings	10	10	0	0	0
Number of buildings with 40-49 dwellings	13	8	5	0	0
Number of buildings with 30-39 dwellings	80	40	35	5	0
Number of buildings with 20-29 dwellings	49	20	15	12	2
Number of buildings with 10-19 dwellings	83	18	20	30	15
Number of buildings with 2-9 dwellings	575	220	150	160	45
Number of detached houses	7 330	2 460	3 250	1 100	520
Length of roads, km	540	20	25	260	235
Length of streets, km	190	60	90	30	10
Total roads and streets, km	730	80	115	290	245
Average size of household	2,3				
Waste generation and sorting, previous year					
Mixed municipal waste (MMW - 20 03 01), t	6 950	2 400	3 100	1 100	350
Bio-waste (BW - 20 01 08, 20 02 01), t	160	75	60	20	5
Paper and cardboard (PC - 20 01 01), t	570	200	250	80	40
Packaging waste (PW - 15 01 06), t	690	240	300	100	50
Rate of bio-waste sorting, %	2,1%	2,8%	1,8%	1,7%	1,3%
Rate of paper waste sorting, %	7,4%	7,5%	7,3%	6,7%	10,1%
Rate of packaging waste sorting, %	9,0%	9,0%	8,8%	8,3%	12,7%
MMW per capita kg/year	273	293	274	224	318
BW per capita kg/year	6	9	7	4	5
PC per capita kg/year	22	24	30	16	36

The Tool is composed of 9 different worksheets, including introduction, input data and results, which are successively equipped with formulas fed by the input data. On the introduction page, the instructions how to fill the input cells, with what kind of data and where are the cells located. On the following pages OWCS service volumes and turnovers are calculated, the potential of source sorting and central collection of BW and PC is presented, the actual transportation costs are figured out, the carbon footprint arising from treatment operations and transportation is assessed and tender evaluation models for two different project scenarios are compiled. The Tool is applicable for a single municipality or for a bunch of municipalities aiming to cooperate.

4.2 Description of the input data

The input data consists of the data which is mostly available from public databases and registers or in the possession of local authority. The necessary demographical, territorial and infrastructural data are number of inhabitants, size of the territory, structure of dwellings (number of detached houses, number of buildings with 2-9, 10-19, 20-29, 30-39, 40-49 and 50+ dwellings), length of the roads and length of the streets. These data are available on the websites of KOP, BSE and Register of the Roads. The size of the household is optional and entered as a constant – 2.3 (BSE, 2012). The data is entered separately by each municipality, and summed up by the Tool.

The amounts of MMW, BW, PC and PW in recent years are available on the webpage of EEIC. The public query can be drawn by municipality, by year, by waste code and by treatment operation (EEIC, 2012). However, the treatment operations are location-based, meaning if the waste collected from a municipality M1 is treated (e.g. composted) in the municipality M2, then treatment (composting) of that amount of waste is accounted to the municipality M2. Basing on the waste amounts, at once the rate of source sorting and waste generation per capita is calculated on the input data page of the Tool.

As to the waste treatment options (composting, incineration, MBT, sorting station, landfill, digestion), the input data, such as distance from the waste collection district and gate fee of the treatment plant) must be filled either relying on the results of the public procurement or selected by the municipality. The paper utilisation costs are to be marked as negative if the paper is sold as secondary raw material. The bulk densities of different waste classes in containers and in refuse collection vehicles (RCV) basing on different studies is presented in the Table 4.

Table 4. Bulk densities of different waste classes

Waste class – waste code	Bulk density (t/m^3)	Source
MMW – 20 03 01	0.13	(Karadimas and Loumos, 2008)
BW – 20 01 08, 20 02 01	0.35	(WRAP, 2009)
PC – 20 01 01	0.11	
PW – 15 01 06	0.08	
MMW in RCV	0.42	(Dim and Cohen, 2013)
BW in RCV	0.50	(WRAP, 2009)
PC in RCV	0.43	

Different types of RCVs and their fuel consumption are presented in the Table 5. The constants for calculation of the carbon footprint arising from different treatment operations and transportation is presented in the Table 6. The constants rely on different researches.

Table 5. Types of RCV (gross bulk in T / size of the compartment in m^3), fuel price

Type of RCV (T/m^3)	Fuel consumption	Source
RCV 32/27	1.27 L/km	(WRAP, 2007), (Nguyen and Wilson, 2010), (Entec, 2010)
RCV 25/17	0.86 L/km	
RCV 18/11	0.57 L/km	
Fuel price, diesel	1.294 €/L	(Neste Oil, 2014)
Fuel price, petrol	1.329 €/L	

Table 6. Carbon footprint constants

Carbon footprint from waste treatment	kg CO_2-eq/tonne	Source
BW landfilling	1,188.3	(EEA, 2014)
BW incineration	-86.7	
BW anaerobic digeston	-88.0	
BW aerobic composting	-45.8	
BW home composting	32.0	
Paper recycling	-1,100.0	(Laurijssena et al., 2013)
MMW landfilling	395.0	(Harish et al., 2013)
MMW incineration	-179.0	
MMW MBT	-172,0	
Carbon footprint from fuel consumption	kg CO_2-eq/L	Source
Diesel	2.63	(Defra, 2005), (IEEP, 2010)
Petrol	2.30	
LPG	1.49	

Waste management budgets in general are available on the website of the Ministry of the Finance (MFER, 2012). When carrying out the survey about waste management in Harju County municipalities, it was revealed that most of the municipalities are capable of keeping account on different waste management costs separately as well. The Tool implies the separate accounting of different costs, such as domestic hazardous waste collection and treatment, running public waste stations and public containers, awareness raising activities, keeping databases and WHR, also outsourced consultancy (legal aid or other), salaries of the officials, and other local expenses (public maintenance, waste collection from cemeteries, etc.).

The number of containers, their emptying intervals and emptying fees are necessary to calculate the volume and turnover of the service. Relying on the § 71^1 of the Waste Act, the local authority has right to get data of the WHR free of charge from the waste collection company. Within the Harju WMC project the data of WHR was collected from the municipalities, the quality of WHRs' data is reviewed in the **Papers II** and **VI** added to the thesis. The typical intervals like weekly, fortnightly, monthly and quarterly do not equal exactly to 52, 104, 12 and 4 times a year respectively, but are specified by the number of days a year. Thus a weekly collection interval equals to 365/7=52.14… times a year, fortnightly to 365/14=26.07…, monthly (=4 weeks = 28 days) to 13.03… and quarterly (=12 weeks = 84 days) to 4.34… times a year.

The distance between the village centres and towns within the inter-municipal waste collection district is necessary in order to calculate the transportation costs of source sorted BW and PC. The average wage of an RCV driver an hour is equalised with the Estonian average hour wage 6.02 € (BSE, 2014b) where to 34% of social security and unemployment insurance charge is added. The average velocity within the collection district and between the collection areas bases on different empirical researches (Boscovic et al., 2013), (Chalkias and Lasaridi, 2009), (Jalilzadeh and Parvaresh, 2005). Basing on the average velocity, the working hours of the drivers are calculated. The labour costs of RCV drivers are counted to the transportation expenditure.

4.3 Description of the outputs

4.3.1 Waste amounts, service volume and turnovers

On the worksheet "Waste" the waste amounts in tonnes and OWC service volume in cubic metres were calculated basing on the collection frequency, number and sizes of the containers and bulk densities of different waste classes. In order to double-check the adequacy of the service volume, the weight of different waste classes were calculated in return basing on the bulk densities and volumes in cubic metres, and compared to the official data from EEIC. Since the containers are never exactly 100% full, sometimes over-filled but more likely a little bit under-filled, and the bulk density is fluctuating seasonally, a 20% deviation from the actual waste amounts was considered as normal.

The volume of service in cubic metres was calculated by multiplying the number of containers of each size separately with each collection frequency and summing up each category. On the worksheet "Turnovers" the size of the container was replaced by the collection fee of particular type of container, and same calculations were processed. The number of routes (Table 7 by example of PC) on the page "Waste" by each type of RCV were calculated as follows:

$N_R = V_W \cdot BD_W / (V_C \cdot BD_C)$, where

N_R – number of routes

V_W – volume of waste

BD_W – bulk density of the waste class

V_C – volume of the RCV compartment

BD_C – bulk density of the waste class in the RCV compartment

Table 7. Service volume and number of routes by case of PC.

Service volume PC		Container volume, m³				Total PC, tonnes	Number of routes a year		
Interval (times/y)		0,24	0,60	0,80	2,50		T32/27	T25/18	T18/12
weekly	52	1	40	10	10	2,985	28	42	63
fortnightly	26	4	30	5	5	924	9	13	20
monthly (28 days)	13	3	80	35	20	1,652	16	23	35
Number of emptyings/y		196	3,911	1,108	913				
TOTAL PC m^3/y		47	2,346	886	2,281	5,561	118	177	284
TOTAL PC tonnes/y		5	258	98	251	612			

The potential volume and turnover of the BW and PC collection services were calculated on the basis of the number of buildings with 10 and more dwellings and fixed collection intervals. The containers with size of 0.14 and 0.6 m^3 (depending on the number of dwellings in the building) were taken as the typical bins for the BW with weekly collection frequency. Containers with size of 0.8 and 2.5 m^3 were taken as the typical container for the PC with fortnightly and monthly collection frequency depending on the number of dwellings in the building. For the inhabitants residing in detached houses and buildings with less than 10 dwellings one 4.5 m^3 "bring collection" container per 1,000 capita with monthly collection interval was considered in addition to the "private" containers (Table 8).

Table 8. BW and PC containers and collection frequency

Interval / container volume	0.14 m³	0.6 m³	0.8 m³	2.5 m³	4.5 m³
	Number of dwellings in the building				Public
Weekly, BW	10-39	40+	n/a	n/a	n/a
Fortnightly, PW	n/a	n/a	20-29	40+	n/a
Monthly (28 days), PW	n/a	n/a	10-19	30-39	13

4.3.2 Transportation, treatment and administrative costs (page „Economics)

The actual transportation costs were calculated by types of RCV on the basis of the number and length of the routes (kilometres per RCV), different velocities on different stages of the route (=hours per route), fuel consumption of the different types of trucks, price of fuel, and hour wage of the driver.

On the Table 9 the MMW calculations are given as example and total transportations costs by types of RCV per each waste class are presented. Since the

RCV T32/27 was the cheapest in terms of fuel consumption and labour hours together in all the positions this was the type of RCV used for the procurement models and in comparison of different scenarios when drawing the results. The fuel consumption was not differentiated by different stages of the waste collection route where the velocity of RCV is different in order not to overload the model with transportation specific details.

Table 9. Transportation costs by RCV and routes of MMW, and total by all waste classes.

Table 9a.	Number of routes a year			Kilometres a year			Hours a year		
MMW	T32/27	T25/18	T18/12	T32/27	T25/18	T18/12	T32/27	T25/18	T18/12
Route 122	93	139	209	30,608	45,912	68,868	3,081	2,891	2,372
Route 52	289	433	649	95,217	142,826	214,239	9,586	8,993	8,790
Route 26	189	284	426	62,433	93,649	140,474	6,285	5,896	5,293
Route 13	100	150	225	52,987	79,480	119,220	3,960	5,940	8,910
Route 4	6	10	14	1,785	2,678	4,017	41	62	92

Table 9b.	Fuel a year, L			Fuel a year, €			Labour a year, €		
MMW	T32/27	T25/18	T18/12	T32/27	T25/18	T18/12	T32/27	T25/18	T18/12
Route 122	38,872	39,485	36,500	50,301	51,093	47,231	24,857	23,319	19,131
Route 52	120,926	122,830	113,547	156,478	158,943	146,930	77,327	72,543	70,906
Route 26	79,290	80,538	74,451	102,601	104,217	96,340	50,702	47,565	42,702
Route 13	67,293	68,353	63,187	87,077	88,449	81,764	31,945	47,918	71,877
Route 4	2,267	2,303	2,129	2,934	2,980	2,755	331	497	746

Table 9c.

Transportation costs, €/y	MMW fuel	MMW labour	MMW total	PC fuel	PC labour	PC total	BW fuel	BW labour	BW total
T32/27	399,391	185,164	584,555	27,644	14,040	41,684	8,185	3,939	12,125
T25/18	405,681	191,843	597,524	28,079	21,061	49,140	8,314	5,909	14,223
T18/12	375,019	205,362	580,381	25,957	31,591	57,548	7,686	8,863	16,549

The treatment costs were calculated simply on the basis of waste amounts and gate fees of (selected) waste treatment facilities. In the case of PC, the treatment costs are presumed to be negative since the PC can be sold as secondary raw material on the market.

4.3.3 Administration coefficient and administrative efficiency

Administrative and public waste management services costs were calculated for three different scenarios, Base Scenario, project Scenario S1 and project Scenario S2. The cost were divided into three:

1) Administrative expenses involve costs of keeping WHR, awareness raising activities, and salaries of the officials;
2) The public waste management services cost involve management of the public waste stations, collection points and domestic hazardous waste collection and transport;
3) The expenses not included to the administration coefficient were those of outsourced consultancy and legal aid, and some waste management costs

like public maintenance and waste management on cemeteries.

For the Scenario S2, the administration coefficient was calculated basing on the service volume – all the included expenses were divided proportionally on all types of containers considering the size of the container and number of its emptyings a year. The administration coefficient presented in the Table 10 is added only to the emptying fees of MMW containers in case of Scenario S2, which is the advanced OWCS. Thus the polluter-pays principle is applied through the administration coefficient by integrating the costs of public waste management services into the MMW collection fee. In case of Scenario S2 the municipality's budget is freed from these expense and transferred on the waste holders wallet.

Table 10. Administrative coefficient for S2

Total administrative coefficient added to MMW S2 only, €/emptying								
0.1 m^3	0.14 m^3	0.24 m^3	0.36 m^3	0.6 m^3	0.8 m^3	1.1 m^3	2.5 m^3	4.5 m^3
0.19	0.27	0.46	0.69	1.15	1.53	2.10	4.77	8.59

The work-loads and number of officials depend on the scenario. For the Base Scenario the actual number of officials (6 officials for the sample municipalities basing on the interviews and mapping of the Harju County waste management situation within the Harju WMC project) were counted with the work-load of 0.73, and the presumed costs of outsourced consultancy were accounted on the salary fund of the Base Scenario. Scenario S1, an inter-municipal WMC which takes over only part of the waste management tasks and the advanced OWCS is not applied, it takes 2 full time officials plus 0.33 work-load of the existing officials. The salaries fund was calculated accordingly, the salary 1,553.33 €/month (including social security and unemployment insurance) was addressed only to the 2 full-time officials of the WMC, the municipal officials earned their basic salary. For the Scenario S2, the full-scale project scenario, 4 basic officials independent on the number of members nor inhabitants comprised in the member municipalities, plus 0.25 work-loads per each 10,000 inhabitants, were counted. Due to the higher level of competence and full work-load, the salaries of the WMC officials in case of S1 and S2, are 20% higher than that of Base Scenario. The Estonian average salary, 996 € was taken as etalon (BSE, 2014b), where to 34% of social security and unemployment insurance charge was added.

4.3.3 Carbon footprint

The carbon footprints arising from the transportation and treatment of PC and BW is analysed in the **Paper VI**. The carbon footprint comes to the subject mostly in case of BW and PC collection and treatment in order to help to assess the environmental feasibility of source sorting and central collection of these waste classes. Carbon footprint was calculated for each type of RCV considering the fuel consumption and covered kilometres, and each waste class considering the type of treatment operation and amounts of waste basing on the constants of carbon footprint expressed in CO_2 emissions presented in the Table 6.

The lowest and highest emissions from all the treatment operations and all types of RCVs were detected. When combining the carbon footprint for both of the transportation and treatment, the default distance from the treatment plant determined on the page "Economics" of the Tool was considered for all the treatment operations.

The main questions regarding carbon footprint arising from separate collection of BW and PC were: 1) do the CO_2 emissions from transportation cancel out the CO_2 savings arising from paper recycling; and 2) is the transportation of the BW justified in case aerobic composting instead of home composting if expressed in CO_2 emissions.

4.3.4 Tender evaluation models and formation of the OWCS service fees

The tender evaluation model for the OWCS public procurement is introduced in the **Paper V** added to the thesis. The main differences between S1 and S2 is that in case of S2 the treatment and collection procurements are held separately, and the administration coefficient is added to the emptying fees of the MMW containers. The results of the procurements (gate fees of the treatment facility and collection fees) of both cases feed the input of the service fees and turnover calculations. A fake procurement was processed where 5 imaginary tenderers (relying on the experience of the author) were competing. On the Table 11, results of the S1 procurement are presented as an example of the model.

Table 11. Results of the OWCS procurement for scenario S1.

Table 11a. INPUT – COLLECTION FEE (€), MMW

Type of container	volume, m^3	Winner (T3)	T1	T2	T3	T4	T5
Type BAG <10 kg	0.1	2,50	1,50	1,00	2,50	1,70	2,00
Type R1 (2 wheels)	0.08-0.18	3,00	3,80	3,50	3,00	3,20	3,50
Type R2 (2 wheels)	0.24-0.4	3,00	4,00	3,90	3,00	4,00	3,80
Type R3 (4wheels)	0.6-1.1	5,50	6,20	5,90	5,50	5,00	5,60
Type S1 (w/o wheels)	1.5-4.5	9,00	8,70	6,00	9,00	7,20	9,20
Treatment facility gate fee		48,00	50,00	60,00	48,00	50,00	50,00
Annual waste generation, t	6,950						
Type of treatment facility			MBT	Landfill	Inciner.	MBT	MBT

Table 11b. RESULTS – ANNUAL COLLECTION FEE (€), MMW

Type of container	volume, m^3	number of emptyings a year	T1	T2	T3	T4	T5
Type BAG <10 kg	0.1	500	750	500	1,250	850	1,000
Type R1 (2 wheels)	0.08-0.18	1,700	6,460	5,950	5,100	5,440	5,950
Type R2 (2 wheels)	0.24-0.4	290	1,160	1,131	870	1,160	1,102
Type R3 (4wheels)	0.6-1.1	50	310	295	275	250	280
Type R4 (w/o wheels)	1.5-4.5	8,721	75,872	52,325	78,488	62,790	80,232
Winner T3 annual Collection Fees, €		***489,556***	588,132	552,165	489,556	536,815	555,921
Winner T3 annual treatment cost, €		***333,600***	347,500	417,000	333,600	347,500	347,500
Winner T3 total annual service, €		***823,156***	935,632	969,165	823,156	884,315	903,421

The OWCS is a public service which is organised by local authority and executed by private enterprise, thus the service quality and price must be fair and reasoned. The cross-subsiding between transportation and treatment of municipal waste is not directly restricted, however it is against the requirement of the Waste Act § 66 psg. 5, according to which the waste collection fee must be sufficient to cover the costs of establishment, operation, close-down and after-care of the waste treatment facility, and also the costs of preparation the transportation (administration, customer service, accounting, etc.) and transportation costs.

4.4 Waste management cooperation and competence centre

The model and different scenarios of a WMC are described in the **Paper III**. Ideally, a WMC would take over the waste management tasks mentioned in the section 3.5 from its members, so that the only duties left on the municipalities' shoulders were the enforcement of legislation and executing supervisory. There are two sources for financing of the WMC: the municipalities and the waste holders.

In case of implementation of the polluter-pays principle at full-scale, all the expenses (administration, customer service, awareness raising activities, WHR, public waste stations and collection points, domestic hazardous waste collection) are integrated to the MMW collection fees, proportionally to the size of container considering that the bigger the container the more waste holders it serves and the bigger is the administration coefficient. This financing model requires the implementation of the advanced OWCS, in which the waste collection fees are collected by the WMC (Scenario S2). Naturally, the waste collection districts are formed inter-municipally and the collection and treatment services are separated. Improvement of the administrative efficiency (and competence) is strongly expected as well as some fall in prices of waste collection and treatment services due to the scale effect from the larger waste collection districts. However, a raise in waste collection fees is expected, since the administration coefficient is added.

In case of the Scenario S1, although the WMC takes some or all of the waste management duties, the public waste management services remain to be financed by the municipalities, in this case through the member fees paid to the WMC, which would cover the expenses of the public waste management services. In the other words, nothing changed in the financing scheme except the service provider. The point in case of Scenario S1, is the improvement of the administrative efficiency (and competence), due to which some savings in the salaries fund are expected, and the need for exterior competence falls off. The waste collection fees may drop due to the scale effect if inter-municipal waste collection districts are formed. Only if the domestic hazardous waste is involved to the OWCS, the polluter-pays principle can be applied partly on the public waste management services. Naturally, then the OWCS service fee will raise accordingly, especially, that this very expenditure is usually one of the highest in the municipality's budget. In this case same formula as used in case of S2 administration coefficient can be applied in order to calculate the extra for the hazardous waste collection and treatment to the service fee.

4.5 System boundaries

The Tool does not attempt to present precise economical features, a business plan, nor environmental report of the observed waste management model. Neither replaces the Tool any LCA model. The socio-economic cost-benefit analysis, risk and sensibility analysis, and the financial prognosis of a WMC were drafted within the Harju WMC project. Detailed LCA researches of different waste management scenarios and treatment options in Estonia have been carried out by Moora (2009) and Voronova (2013). The Tool aims to assess: 1) the economic feasibility arising from inter-municipal cooperation; 2) the improvement of the administrative efficiency arising from the inter-municipal cooperation; 3) the economic and environmental feasibility of central collection of source sorted BW and PC; and 4) configure a fair tender evaluation model for the OWCS public procurement, either for the classic or advanced form. It is a simplified model which considers only the main indicators, leaving rest of the variables aside by ceteris paribus principle.

The variables most sensitive to deviation are the number of containers and their emptying intervals, length of the routes, and velocity of the RCV in the collection area, since the majority of the economic and environmental costs base on these figures. However, the deviation propagates proportionally. E.g. if the real service volume (the number of all types of containers with each collection interval) differs twice or more or less, the costs on transportation and labour increase or decrease proportionally. Yet the deviation in the length of the routes and the velocity of RCV within the collection area may distort the economic feasibility, if the deviation is bigger than 20%.

Although the input data consists of amounts of packaging, and constants about petrol and LPG, these figures are of more like illustrative meaning. In the current research, only the collection and treatment of MMW, BW and PC are analysed, and the transportation costs are calculated on the diesel driving RCVs in order to maintain the simplicity, and to offer reasonable number of comparisons, in consideration of the as few as possible principle. In case of the need, it is facile to extrapolate the same calculations on different types of fuels and more waste classes. Thus, the Tool has straight potential for far more complicated modelling.

The calculations cover only three main waste classes, MMW, PC and BW. The PW and WEEE are left out on the consideration that these waste classes are covered with the producer's responsibility, and are not subject of the OWCS. As to the domestic hazardous waste, only general costs borne by the municipalities are involved, which may not reflect the real costs if the domestic hazardous waste were involved to the advanced OWCS. It is presumed, that these costs remain the same also in case of both project scenarios.

The existing network of public waste stations and collection points is considered sufficient at the moment, and expanding the network of collection points will probably not increase the rate of source sorting and recycling enough to justify the cost (both economic and environmental) of material and operation of the collection points. In addition, some experiences of the author indicate that management of the public waste stations may not necessarily be unprofitable as it is commonly thought to be but in some conditions a public waste station can also be self-sufficient. This issue can be an independent subject for further research.

Two important aspects – investments to the waste management infrastructure, and establishment costs of the WMC are not disserted in the thesis. It is clear, that the establishment of a WMC brings along some extra costs – these are analysed in Järve (2012), and briefly reviewed in the **Paper II** and **III** added to the thesis. Another aspect – the political – is left aside in consideration of its immaterial and unscientific characteristics.

The establishment costs of a WMC could involve beside the fee for registration an organisation also expenses on office and its equipment, licences for computer software like accounting, logistics and customer service programmes etc., however, the investments can be avoided by renting all the instead of buying. The only period when the WMC is not self-sufficient, is from the establishment till the first payments of the service fees by the waste holders, which is about half a year. Thus, financial support is needed either in shape of member fees paid by the municipalities or a circulation loan in order to cover the expenditure on salaries, office, equipment and licences rent during the transition period.

The financial scheme of Scenario S2 will work fairly only in case of 100% of collection coverage, meaning all the households without any exceptions are involved to the OWCS, otherwise the public utilities are exploited by those who have not fairly paid for them.

4.6 System optimisation

In the current thesis, the integrated system optimisation is carried out in focus of three aspects: (i) examination of the source sorting efficiency and requirements, suggesting rearrangements in the current scheme; (ii) improvement of administrative and economic efficiency through inter-municipal cooperation; and (iii) improvement of the municipal waste collection logistics, cutting the environmental and economic load arising from the transportation by forming over-boundary waste collection districts. The source sorting of BW and PC are reviewed in the **Papers II** and **VI** added to the thesis. The impact and utilisation aspects of BW, including the biogas potential, are disserted in the **Papers I** and **IV** added to the thesis. Principles of the reorganisation of the waste management through the cooperation organisation, and the socio-economic aspects of the inter-municipal waste management cooperation are introduced in the **Papers II, II** and **VI**. The impact of tender specifications and evaluation model on the waste collection fees and the quality of the OWC service, also the benefits arising from the over-boundary waste collection districts are analysed in the **Papers V** and **VI**. The optimisation of the waste collection logistics through inter-municipal waste collection districts is discussed in the **Papers II, III** and **VI** added to the thesis.

5 RESULTS AND DISCUSSION

There are several researches aiming to improve the administrative and economic cost-efficiency, and to reduce the environmental impact of the municipal waste management applying different info-technological tools and models. These researches involve GIS (Geographic Information System), DSS (Decision Support System), IWMM (Integrated Waste Management Model), CBA (Cost Benefit Analysis), NPV (Net Present Value), LCA (Life Cycle Assessment), WAMPS (Waste Management Planning System), PAYT (Pay As You Through), (ISM) interpretive structural modelling, etc.

GIS was used to improve the efficiency of waste collection and transport in the Municipality of Nikea, Athens, Greece via the reallocation of waste collection bins, the introduction of new vehicle routing and new vehicle time (Chalkias and Lasaridi, 2009). Xiangyun *et al.* 2007 presented the development of DSS, which elaborates on the construction of databases, the evaluation model using NPV, and the development of system to assess effectiveness and profitability of any technological process and to find a cost effective model solution in municipal solid waste management (Xiangyun et al, 2007). Hrebicek and Soukopova, 2010 applied environmental modelling, particularly modelling of Integrated Municipal Solid Waste Management Systems (IWMM) at the Czech Republic to simulate the different scenarios of prescribed waste landfill fees, an inclusion or an exclusion of certain facilities of energy recovery / mechanical-biological treatment of waste with prescribed annual capacity in selected locations (Hrebicek and Soukopova, 2010). The economic feasibility of the reorganisation of municipal waste collection service in Harju County was assessed by calculating FNPV and expanded FNPV of the different waste management scenarios (Järve, 2012). Moora (2009) and Teibe et al. (2013) applied WAMPS to evaluate the environmental impacts of different waste management scenarios regarding the municipal treatment options. The modelling based on social-economic indicators (regression implemented in LCA-IWM model) showed particular sensitivity to external factors, such as the synergetic effects of affluence parameters or changes in MSW collection system (Rimaityte et al., 2012). The PAYT system applicability in Estonia was analysed by Voronova (Voronova, 2013). Tseng and Lin applied interpretive structural modelling (ISM) to proposed 18 criteria for Taipei metropolitan to assist the expert group to compose the municipal solid waste management hierarchical framework (Tseng and Lin, 2011).

All these abovementioned works conclude in common statement: municipal waste management is a field of activity which comprises a remarkable environmental impact and economic expenses which can be reduced by optimisation of the waste collection and treatment system, and has a considerable social aspect which presumes involvement of stakeholders from all the levels. In the current thesis, an inter-municipal cooperation model example was assessed from the aspects of administrative, environmental and economic feasibility.

5.1 Inter-municipal cooperation

It is already concluded in the **Paper II** and **III**, that the FNPV is positive in case of both project scenarios, S1 and S2, meaning the local authorities would win financially anyway if a WMC would be established by the Harju County municipalities. Also Hogg (2001) states, that usually, where processes are more capital-intense; where they are operated by the private sector; and where the lifetime of the capital equipment is extended, the financial costs generated through the common accounting framework discussed are likely to deviate from those which are actually quoted to local authorities, meaning they will typically be lower than such quotes (Hogg, 2001). Although there is no doubt, that the inter-municipal cooperation is beneficial for the small municipalities, the question remains, from which scale the cooperation organisation with independent administration and employees becomes more beneficial than just a contractual cooperation between few municipalities.

5.1.1 Administrative efficiency

Administrative efficiency can be measured by the number of officials at service of a number of inhabitants, e.g. per 10,000. Clearly, a basic duties must be performed independent on the size of the municipality, and therefrom the potential for the cooperation arises. By case of Tallinn City, roughly 1 official per 25,000 were sufficient to fulfil all the public waste management tasks. However, if there are 4-5 different tasks which need specialisation, in order to maintain the level of competence and good quality of the services, one specialist should be hired per task. Thus, an optimal size of the regional WMC would be about 100,000 to 125,000 inhabitants.

In the current thesis the administrative efficiency was assessed by case of 4 rural sample municipalities comprising altogether 25,500 inhabitants. If by ceteris paribus principle all the other expenses were left aside, and only work-load and salaries fund were compared, then the most efficient scenario was S1, barely but still more efficient compared to S0. As soon as the number of inhabitants, and accordingly number of official were manually doubled, the cooperation gained far more advantage (Table 12 and Table 13). However, lowering the number of inhabitants to 15,000 and number of municipal officials to 4, the WMC of both project scenarios seemed to lose its advantage (Table 14).

Table 12. Salary fund in case of different scenarios, 25,500 inhabitants

Administrative efficiency	Officials	Work-load	Total hrs/y	Salary, €/m	Salary fund, €/y
Current administration S0	6.0	0.73	8,848	1,294.44	71,535.77
Administration S1	4.0	1.00	8,040	1,553.33	68,035.77
Administration S2	4.6	1.00	9,368	1,553.33	86,442.70

Table 13. Salary fund in case of different scenarios, 50,000 inhabitants

Administrative efficiency	Officials	Work-load	Total hrs/y	Salary, €/m	Salary fund, €/y
Current administration S0	12.0	0.73	17,695	1,294.44	139,571.53
Administration S1	6.0	1.00	12,039	1,553.33	98,791.66
Administration S2	5.3	1.00	10,605	1,553.33	97,859.66

Table 14. Salary fund in case of different scenarios, 15,000 inhabitants

Administrative efficiency	Officials	Work-load	Total hrs/y	Salary, €/m	Salary fund, €/y
Current administration S0	4.0	0.73	5,898	1,294.44	48,857.18
Administration S1	3.3	1.00	6,706	1,553.33	57,783.80
Administration S2	4.4	1.00	8,838	1,553.33	81,549.72

The administrative efficiency of the existing WMCs in Estonia is presented in the Table 15. All the WMCs are running S1 model. The number officials is calculated according to Scenario S1 – to the number of employees of the WMC 0.33 work-loads of municipal officials is added. Hiiumaa used the administration of the Union of Hiiu County Municipalities, no additional specialists were hired, but existing competence was used in addition to the municipal officials (Hiiumaa, 2014). The only employer of HÜK is a chief, manager and specialist in one person (HÜK, 2014). IEJHK has a chief and a project manager (IEJHK, 2014). KEJHK has in addition to the chief two more project managers/specialists (KEHJK, 2014). LVOL, similar to Hiiumaa has one specialist dealing with the waste management issues, particularly OWCS regarding issues (LVOL, 2014). RJKK is run by one chief, manager and specialist in one person (RJKK 2014). VPKK has a chief and three specialist to run the waste management in the county (Karu, 2009). According to Table 15, HÜK seems to be the most efficient WMC.

Table 15. Administrative efficiency of Estonian WMCs

WMC	Emplo-yees*	Munici-palities	Muni-cipal officials	Inhabi-tants	Terri-tory	Number of waste collection districts	Officials per 10,000 inhabi-tants
Hiiumaa	2	4	4	9,310	1,023	1	3.6
HÜK	1	9	11	65,857	3,218	6	0.7
IEJHK	2	9	9	17,133	1,912	1	2.9
KEJHK	3	27	34	77,653	7,660	8	1.8
LVOL	1	6	6	12,307	1,582	1	2.4
RJKK	1	3	3	17,844	626	1	1.1
VPKK	4	13	13	32,178	2,044	2	2.6

* the accountant and secretary excluded

5.1.2 Scale-effect from transboundary waste collection districts

According to several researches the main costs and environmental load of municipal waste collection arises directly from the transportation, in other words, from kilometres and time covered by the waste collection trucks (Beijoco et al., 2011; Boskovic et al., 2013; Jalilzadeh and Parvaresh, 2005; Shamshiry et al., 2011). It is reasonable to consider that even small improvements in this area can lead to significant financial savings. Moreover, these procedures imply the existence of considerably high fuel consumption and pollutant emissions, since the activities involved are performed by heavy road vehicles. Thus, significant benefits can be derived from the optimization of MSW collection and transportation routes as well (Beijoco et al., 2011).

Chu et al. (2013) modelled different waste collection scenarios, and found that in a hypothetical city of 20,000 households the best option to reduce the overall fuel consumption was a weekly food waste collection with alternate weekly collection of the recyclables and residual waste by two-compartment collection vehicles. In general, the fuel consumption for collecting the complete household waste stream decreases when the capture rates for co-mingled recyclables and for food waste increases. Small collection vehicle is ideal for the collection of small amount of waste, such as food waste, at each pick-up point at the low capture rates; while a larger collection vehicle such as the 26-tonne RCV is well suited to residual waste collection. The study also showed that the two-compartment RCV is not always fully utilised and is usually limited by the volume of the compartment rather than the vehicle payload during co-collection of household waste. In some cases, the single separate collection of the household waste could consume less fuel than the co-collection by compartmentalised vehicle, when the collection frequency is reduced to fortnightly collections.

It is indicated in the Waste Act that size of the waste collection district should generally not exceed 30,000 inhabitants, and be determined by the estimation that the minimal size of the waste collection district provides the fill-up of the RCV in one collection route (EP, 2004, § 67 psg. 5), in other words, the logistical scheme of the waste collection should be optimal. Therefore, the potential and advantages of the transboundary waste collection districts should be exploited. The inter-municipal cooperation is essential in order to provide a high quality public waste management services unless a municipality comprises at least about 30,000 inhabitants.

The projected inter-municipal waste collection districts are presented and discussed in the **Papers III** and **VI** added to the thesis. In addition to the improved logistical efficiency, the enlarged inter-municipal waste collection districts are more attractive to the competition on the OWCS public procurements. The enlarged inter-municipal waste collection districts also equalise the service availability and pricing throughout the region, both in village centres and peripheries.

An important factor regarding the enlarged waste collection districts is optimisation of the waste collection routes. In the case of Harju County, and also in other rural areas in Estonia, the roads between and to the sparsely located households are often with low load-bearing capacity, and may seasonally be not passable for a heavy RCV. In this case the usage of smaller RCVs needs a well-planned logistics in order reduce the “empty” kilometres. To keep a variety of different types of RCVs just in case, is economically clearly not reasonable. Yet, small waste collection districts may not pose enough collection load for two or more different type of RCV.

5.2 Separate collection of bio-waste and paper

The adoption of a system of separate collection could generate positive impacts on all the stakeholders involved in the solid waste management sector and could contribute to the compliance of European standards in many Central and Eastern European countries as established by a number of national environmental protection strategies (Vaccari et al., 2013).

The approach of potential service volume of BW and PC was applied in the current research due to the poor quality of the WHR data of Harju County municipalities and insufficient application of source sorting of these waste classes in the municipalities. When analysing the WHRs it was clearly revealed that the number of containers, their emptying intervals (data of WHR) and actual waste amounts reported in EEIC by far did not match (**Paper VI**). Comparing the number of containers to the number of buildings with 10 or more dwellings, where according to the local waste regulation a separate container for BW and PC should have been, it was clear that source sorting is not applied at full scale. Thus, these data was considered as improper for the analysis, and relevant input, such as the number of buildings with 10 or more dwellings, and number of dwellings was used instead to determine the sizes of the containers and their collection frequency.

5.2.1 Paper waste

The source sorting of PC has long-term practice in Estonia. In most of the municipalities it is banned to throw the PC to the MMW bin, and buildings with 5 or 10 dwellings must have separate container for PC. In many municipalities there are also public collection points for PC along with the PW containers, and certainly the public waste stations accept source sorted PC. However, the MMW still contains some PC (Table 2).

There are direct targets and requirements set in the EU and local legislation regarding recycling and recovery of PC. The Waste Framework Directive Article 11 (2a) says inter alia that by 2020, recycling of waste materials such as at least paper from households shall be increased to a minimum of overall 50 % by weight (EC, 2008). Arising from the Waste Act (§ 31 psg. 2, will be enforced by Jan 1st, 2015) and Waste Framework Directive Article 11, the local authority shall set up separate collection for at least the following: paper, metal, plastic and glass (EP, 2004 and EC, 2008a). Thus, the separate collection of PC is required and should be improved in order to meet these criteria.

"Bring collection" is a term covering very different systems, from neighbourhood collection points to central civil amenity sites, and it is therefore difficult to find data that cover all of these options. However, it is unlikely that the recycling targets can be reached with less than 1 collection point per 1,000 inhabitants (Koneczny and Pennington, 2007). Thus, in addition to the kerbside collection system, some "bring collection" containers were added to the potential PC collection scheme in consideration of the number of inhabitants residing in the detached houses and buildings with less than 10 dwellings.

In order to assess the environmental feasibility of source sorting and central collection of PC, the carbon emissions arising from the transportation and carbon savings from recycling were calculated for the example municipalities. In case of the potential PC collection scheme, the carbon savings were 821 tonnes of CO_2-eq while the emissions from transportation in case of 25-tonne RCV were around 70 tonnes of CO_2-eq. In case of incineration and anaerobic digestion the savings were roughly equal to the emissions arising from transportation. All the other treatment options – landfilling, aerobic composting and home composting contributed to the CO_2 emissions (Table 16). Thus, clearly the central collection and recycling of paper is environmentally more beneficial than any other treatment option.

Table 16. Carbon emissions in case of potential PC collection scheme.

Operation	t CO_2-eq
landfilling	886,8
incineration	-64,7
anaerobic digestion	-65,7
aerobic composting	-34,2
home composting	23,9
recycling	-820,9
transport RCV T32/25	68,5
transport RCV T25/18	69,6
transport RCV T18/12	64,4

Table 17. The costs and profit of the potential PC collection scheme in case of Base Scenario

Potential PC collection, Base Scenario	m^3	Base Scenario, €
Turnover	6,784	10,005
Treatment costs		-16,417
Transportation costs T32/27		33,723
Labour costs T32/27		17,128
Total		34,434
Gap		-24,429

To assess the economic feasibility of central collection of source sorted PC, the transportation and labour costs were calculated and compared to the possible profit from the marketing of the PC as secondary raw material (Table 17). The turnover of the potential PC collection scheme is presented in the Table 18. The average price for baled paper waste has fluctuated in Europe within last 11 years from 87.30 €/t (2009) to 162.90 €/t (2011) being 132 €/t in 2013 (EDCW, 2014). In Estonia the price for mixed paper waste is 32 €/t (EM, 2014), which was taken as base for the treatment costs calculations, however, this is not a wholesale but retail price.

Table 18. The turnover of the potential PC collection scheme in case of Base Scenario

Service fee PC		2.50 €	2.50 €	2.50 €	Total. PC
Interval/container volume, m^3		0.80	2.50	4.50	
fortnightly	26	49	23	0	
monthly (28 days)	13	83	80	13	
TOTAL PC €/year		5,899	4,106	439	10,005

As revealed from the Table 17, in case of PC selling price 32.00 €/t and collection fee of 2.50 € per emptying for all types of containers, the service is not economically feasible. However, if the price of PC was risen to 65.00 €/t, the whole scheme shifted slightly positive, and in case of selling price of 132.00 €/t, the service could be provided free of charge. Considering that the observed example waste collection area is relatively sparsely populated, and realistically the baled paper could barely be sold for maximum price, it seems that the PC collection is economically feasible only if the service is charged.

5.2.2 Bio-waste

Sundberg et al. (2011) studied the chemical, physical and microbiological characteristics of source-separated bio-waste collected in Finland, Norway and Sweden. The quality of the wastes investigated in that study, with low pH, high organic acid content and lactic acid bacteria present, poses a serious challenge, which, unless properly met, can substantially delay a successful composting process. For efficient composting, it is recommended that food waste be mixed with ample amounts of recycled bulk material and compost, provided that this has a pH well over 6. This helps to buffer the pH, as well as to increase the numbers of bacteria needed for a good composting process.

The results from the environmental assessment of the solid waste system in the Municipality of Aarhus showed that there were no major differences in most of the potential environmental impacts, nor in the consumption of resources whether the source-separated organic household waste was anaerobically digested or combusted at an incineration plant (Kirkeby et al., 2006).

The requirement of separate collection of BW in Harju County municipalities bases only on the example of Tallinn City from the year 2007, and is not supported nor demanded by any legislative framework on national or EU level. The only limit value regarding BW is set in the Waste Act § 134 according to which the biodegradable fraction in the disposed waste may not exceed30% by mass from July 2013 and 20% by mass from July 2020. Another restriction set in the Waste Act § 35 is a direct ban to landfill untreated waste (EP, 2004a). Analyses on the composition of MMW (Moora, 2008; Moora 2013; Table 2) reveal that the implementation of BW source sorting has not been efficient enough to fulfil the target values set in the Waste Act § 134.

Considering the MMW generation in Harju County was 31,397 tonnes in 2012 (EEIC, 2012), this amount consisted of approximately 10,000 tonnes of BW and total 14,200 tonnes of biodegradable fraction. Only 1,027 tonnes of BW was source sorted and collected separately, and even the potential BW amounts are less than 3,000 tonnes if the separate collection of BW were implemented strictly in all the buildings with more than 10 dwellings in Harju County. The MMW generated in Harju County is, in accordance with the principle of proximity, treated either in Iru CHP incineration plant, Ragn-Sells MBT plant or TRC's MBT plant, which inter alia treat the biodegradable fraction as well.

Thus, the alternative option to central collection of bio-waste is home composting or thermal or biological treatment of the MMW. As to biological treatment of MMW, in Estonia MBT can be applied at 2 landfills out of 5 (Jõelähtme, Uikala), the only MMW incineration plant is Iru CHP Power Plant next to Tallinn. The potential of bio-gas production from source separated bio-waste is weak due to the lack of bio-gas plants and high transportation costs. Increasingly, countries with bio-waste collections, notably Flanders (Belgium), Austria and Germany, promote home composting quite strongly (Hogg, 2001).

Direct landfilling the source separated BW is not only restricted in Estonia, but is an unsustainable method for BW treatment as well in terms of biogas production. According to the **Paper I**, the biogas production rate drops suddenly after the close-down and capping of the landfill, and decreases continually ever after.

Bendere et al. (2007) studied the implementation of BW collection and treatment system in Latvia. According the calculations the transportation costs are increasing with distance. That means it should be much profitable if waste treatment site will be situated close to waste production sites. It is evident from that the larger part from transportation costs makes the fuel expenses.

According to the results of current research, the source sorting and central collection of bio-waste is economically unfeasible in the majority of the Estonian municipalities.

Regarding the Tool analysis of the carbon emissions arising from different treatment operations and transportations, the least emissions arose from anaerobic digestion (Table 19). Even if combined with emissions from transportation, the least carbon emissions were addressed to the anaerobic digestion, not home composting as was expected.

Table 19. Carbon emissions in case of potential bio-waste collection scheme

BW, potential	t CO_2-eq
landfilling	942,9
incineration	-68,8
anaerobic digestion	-69,8
aerobic composting	-36,3
home composting	25,4

The economic feasibility of central collection of BW is discussed in the **Paper VI** added to the thesis. In case of the example municipalities observed in the current research, the service fee must be at least 5.70 € for 0.14 m^3 and 11.00 € for the 0.6 m^3 containers in order to cover the transportation (including labour) and costs. Since these prices are far higher than the fees for MMW containers of same size, the central collection of source sorted BW can be considered economically unfeasible.

In many cases, following the waste hierarchy will lead to waste being dealt with in the most resource-efficient and environmentally sound way. However, in specific circumstances and for specific waste streams, there may be a need to deviate from the hierarchy in order to select the best solution for the environment (Manfredi et al., 2011).

According to Bendere (2011), in Latvia, the composting using windrows was selected as the main method for BW treatment. Till the year 2012, more than 50 new composting sites was planned to be built in Latvia. About 10% of them are created and working at present. Also in Latvia, there is no direct legislation demands to compost production from BW and its usage. The use of BW as new bio mass resource can facilitate the “green energy” production, and be one of the possibilities to implement the decision on replacing fossil fuel for renewable materials in the EC.

Nowadays, the movement towards pay-for-service charges is widespread and generalized. While sometimes calculated on the base of standard indicators (thus with little or no incentive potential), incentive charges are also increasingly diffused, although using rather different schemes (pay-per-bag, per container etc.). Often these schemes entail cross subsidies that favor recycling (low or no charges for separate collection) at the expenses of unsorted waste, on which most of the charge is concentrated (Antonioli and Massarutto, 2011). When implementing the source sorting of BW in Tallinn City, also the limit value of the BW service fee was set in order to keep it lower than MMW collection fee and the waste holders economically motivated to sort the fraction out from MMW. In a city like Tallinn, that kind of administrative measure may be justified by the environmental benefits achieved. However, in rural areas, where the environmental benefits are questionable or non-existing, neither the economic forcing is fair.

5.3 The Organised Waste Collection Scheme

The main principles, objectives, advantages of different OWCS models and their impact on the OWCS fees, and the implementation the OWCS in Estonia are reviewed and discussed in the **Papers II, III, V** and **VI** added to the thesis. In order to highlight the key aspects of the OWCS, following should be pointed out:

- Forced incorporation of the waste holders to the waste collection scheme improves the collection coverage, especially in the rural areas;
- Forced market share improves the availability of the waste collection service in peripheries;
- Contracting to municipality or WMC improves the control over service quality and service fees
- The advanced form of the OWCS enables to integrate the costs of public waste management services to the waste collection fees;
- The OWCS contributes to the development of source sorting and recycling of BW and PC;
- The WHR can perform as an administrative tool for supervisory and statistics if updated periodically;

- Formation of the waste collection fees and service quality depends on the tender specifications and tender evaluation model.

BiPRO (2012) screened the municipal waste management performance in EU member states. The alarming fact is that Estonia scored poorly in some important criteria out of 18, which were "collection coverage for municipal waste", "forecast of municipal waste generation and treatment capacity in the waste management", and "waste prevention programme" (BiPRO, 2012). All the three criteria indicate to the administrative incapability, including implementation of the OWCS. Clearly the above-mentioned key aspects of the OWCS put economical pressure on the waste collection companies compared to the situation on the free market.

Since 2004 when the local authorities in Estonia started to change over from the free market model to the OWCS, the waste collection service public procurements have been continuously accompanied by trials, contentions, and complaints. It has been a common practice that as soon as a public procurement in any local authority has been announced, one or another waste company, a potential tenderer sues the municipality. Over 150 adjudications regarding the OWCS can be found in the Database of the Court Decisions (DCD), most of them solving cases the waste company versus municipality (DCD, 2014). The concealed reason for this kind of counteract is to maintain the market share, and delay the implementation of the OWCS.

The experience of the author in proceeding the public procurements of the OWCS reaches back to the year 2005 while preparing the tender specifications for Tallinn City. The first procurements were characterised by the multiplicity of the tenderers, in some waste collection districts of Tallinn City even up to 13 companies including not only waste collection specialised enterprises but also those from street cleaning sector. Today, only 3 waste collection companies have left on the market, (Ragn-Sells AS (RS) and AS Eesti Keskkonnateenused (EKT) possessing about 95% of market share, and Ekovir OÜ in Eastern Estonia with possession of about 5% of market share. All the rest of the small waste collection companies have been bought up by RS and EKT. The tight competition on the OWCS procurements have wiped off all the small waste collectors and left on the surface only those possessing the treatment facilities.

Another wave of contests during 2010-2012 evolved when some municipalities separated treatment service from collection and tried to implement the advanced OWCS. So far only Tallinn City has succeeded to implement the advanced OWCS, although through the gauntlet of contests. The main argument for separation of the treatment and collection services was to weaken the vertical monopoly and recover the competition on the collection markets. The reason why small companies could not compete with RS and EKT (a former Veolia Group enterprise, major owner of the TRC) in equal conditions was missing of the treatment facility, which in case of RS and EKT gave an indeterminable advantage to them. Both RS and EKT possessed treatment facilities from MBT to landfilling.

Many countries have engaged in competitive exercises, but their success is limited. Compulsory competitive tendering has been successful for specialized phases (collection or treatment as separate activities), but at this level competition is far less successful. Tenders are based on discretional awarding criteria (the "best value" in UK, national variations of the "competitive dialogue" again in the UK, France and Spain) and in most cases the number of bidders is small (one or two). This evident trade-off suggests the need to adopt regulatory structures that are more targeted at countering the market power of these "de facto" monopolies (Antonioli and Massarutto, 2011).

The author has analysed different tender evaluation models practiced in OWCS procurements. The most common evaluation model practiced in the OWC procurements is the merit-point system (MPS), in which different weighs of value are given to different types of containers, thus affecting the tenderers' pricing stategy. For example, if more merit points are attached to the smaller containers (e.g. 80 to 240 litres) compared to the bigger containers (e.g. 600 to 800 litres) then naturally the pressure is on the collection fees of the smaller containers. This may result in the situation where the collection fees of those containers are lower than their net value, and the collection fees of bigger containers which earned less merit points are remarkably higher than they would be in the free market. Then the whole pricing policy bases on the cross-subsiding between small, and big containers, meaning the users of the big containers will pay for the waste collection of users of the small containers. In a settlement of high population density the whole scheme works in opposite way: higher merit points are attributed to the bigger containers, and lower weighs to smaller containers. The most drastic examples of the MPS practice are cases where the collection fee of a smaller container is higher than that of a bigger container (e.g. 2.70 € for a 240 litres container versus 1.94 € for a 600 litres container). The whole scheme is at variance with the polluter pays principle, and gives enough ground for suing the procurements. Therefore a strong need for an adequate evaluation model which enables a fair, and transparent pricing policy has been present already for few years.

As the result of the current research a new tender evaluation model has been worked out both for the regular and advanced OWCS. The model in introduced in details in the **Paper V** added to the thesis. The main points of the new model are separation of the different stages of the service (collection, treatment and administration), and basing on the actual turnover, meaning winner is the tenderer who takes the least amount of money from the waste holders wallet. The whole set of equations (collection, and treatment service separately) has been practiced by HÜK recently (2014), however the new contracts are not enforced yet. The legislative prerequisites are created in also in local waste regulations of some other municipalities (Tartu, 2012; Viljandi, 2011), and hopefully the evaluation model will be implemented in the next round of the public procurements which will be held before the current waste collection contracts end, perspectively within next few years.

6 CONCLUSIONS AND RECOMMENDATIONS

The study aimed to assess:

- socio-economic effects, including changes in the administrative efficiency and optimisation of the waste collection routes through enlarged waste collection districts, arising from inter-municipal cooperation in rural municipalities;
- environmental and economic feasibility of source sorting and central collection of bio-waste and paper waste;
- the impact of tender evaluation models on the OWCS service quality and collection fees,
- and to draw environmentally and economically optimal municipal waste collection and treatment scheme for the municipalities with low population density, where the rural areas are prevailing.

The socio-economic benefits arising from the inter-municipal cooperation are evident independent on the number of municipalities nor inhabitants they comprise. However, the form of cooperation – directly contractual, or organisational through a WMC – and efficiency is scale-bound. Any inter-municipal cooperation is beneficial in terms of improvement administrative efficiency and level of competence. A separate cooperation organisation, a WMC, becomes more beneficial than a contractual protocolled inter-municipal cooperation starting from around 15,000 to 25,000 inhabitants. In this case the role of the WMC is limited to organisational and competence-related functions only. A full-scale shift from municipal administration to WMC-based administration including the take-over of the customer service of the OWCS and management of the public waste services (waste stations, domestic hazardous waste collection, databases and registers, awareness raising activities) becomes cost-effective starting from around 100,000 to 125,000 inhabitants. The full-scale form of cooperation and implementation of the advanced OWCS enables to integrate most of the public waste management costs into OWCS fees, which is supported by the polluter-pays principle.

An optimal size of a waste collection district should be determined by the estimation that the minimal size of the waste collection district provides the fill-up of the RCV in one collection route, which is around 20,000 to 30,000 inhabitants. Thus, most of the waste collection districts, in order to be environmentally and economically cost-effective, should in Estonia be formed on the bases of inter-municipal cooperation. Economic savings are expected form inter-municipal waste collection districts due to the scale-effect. Separation of different stages of the OWCS – administration, collection and treatment – gives a fair basis for the formation of the waste collection fees. The tender specifications may affect the final result and raise the service fee as long as the higher demand on the service quality puts economic pressure on the service provider.

There is no legislative pressure for central collection of BW in rural areas unless the MMW collected from there is going directly to the landfill. As long as home composting is practised in the detached houses, and MMW goes through thermal or mechanical-biological treatment operation, central collection of source separated bio-waste in rural areas can be considered environmentally and economically unfeasible.

There is direct legislative pressure arising from EU Waste Framework Directive and the Waste Act for separate collection of paper and cardboard in Estonia and other EU member states. However, both legislative acts leave it optional if the separate collection would not be technically, environmentally and economically practicable and appropriate to meet the necessary quality standards for the relevant recycling sectors (EC, 2008a). As long as the carbon emissions from paper waste transportation do not annul the carbon savings from paper recycling, and the service is economically feasible, the separate collection of paper waste should be set up in village centres and towns.

FINAL REMARK

By time of the defence of the thesis, an important amendment of the Estonian Waste Act has been proceeded and should have been enforced on 1.10.2014. This is about the Waste Act § 66 psg. 1^1, the green light of the advanced OWCS, which was invalidated by the amendment (SE 455, 2014). It remains fully incomprehensible to the author what was the drive and motivation to the Parliament to invalidate a condition which supported the local authority to take more control over a public service with high social, economic and environmental sensibility – which is the waste management. Fairly, it could not have been a common sense but more like a covered business interest of the waste companies. On 25.92014 the Supreme Court of Estonia satisfied the appellation of 6 municipalities (Sõmeru, Rägavere, Vinni, Kadrina, Rakvere, Nissi) to suspend the enforcement of the mentioned amendment of the Waste Act, and initiated the constitutional supervisory procedure in the case. Although the passage is now nullified, Tallinn City Government has already implemented it, and hopefully the initiative will be spread along the other WMCs in Estonia, regardless the deprivation of the direct legislative support in case the final decision of the Supreme Court will enable the enforcement of the mentioned amendment. Lots of new court cases are expected then in Estonia if any WMC or local authority dares to try to implement the advanced OWCS. However, since similar waste management model is applied in Finland (HSY, Pirkanmaan Jätehuolto), in Germany and Austria (MD48) even at larger scale including municipalisation of waste collection service, in all the European countries the local authorities are taking ever more control over the municipal waste management, this amendment should be reviewed by the European Court of Justice.

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ABSTRACT

"Integrated economic and environmental impact assessment and optimisation of the municipal waste management model in rural area by case of Harju County municipalities in Estonia"

The objective of the thesis was to draw environmentally and economically optimal municipal waste collection and treatment scheme for the rural municipalities where the areas of low population density are prevailing. The research involved the assessment of the improvement in administrative and financial efficiency of waste management arising from inter-municipal cooperation in rural municipalities by case of Harju County municipalities, the analysis of the feasibility of source sorting and central collection of paper and bio-waste, and optimisation of the waste collection logistics by forming inter-municipal waste collection districts.

As the empirical part of the research an Excel based tool was compiled by case of 4 sample municipalities. The main innovation of the tool stands in the availability and simplicity of the input data. The general input data of the current research were the number of population, size of the territories, waste generation, structure of dwellings, and structure of roads – all these data available from the public databases. In addition the data of the organised waste collection scheme (OWCS) contracts, waste collection fees and number, sizes and emptying intervals of the waste containers were applied in the modelling. The tool was composed of 9 different worksheets, which were successively equipped with formulas fed by the input data. On separate pages OWCS service volumes and turnovers were calculated, the potential of source sorting and central collection of BW and PC was presented, the actual transportation costs were figured out, the carbon footprint arising from treatment operations and transportation of bio-waste and paper waste was assessed, and tender evaluation models for two different project scenarios were compiled and tested. The results of each stage were in brief presented on the final page.

The socio-economic benefits arising from the inter-municipal cooperation are evident independent on the number of municipalities nor inhabitants they comprise. However, the form of cooperation and its efficiency is scale-bound. Re-municipalisation of the communal services is a recent trend in Europe, and a recent empirical research has confirmed that there are no significant differences in efficiency between public and private waste operators if the competition between service operators is maintained. The modelling with the tool showed that a separate organisation, a waste management centre (WMC), becomes more beneficial than a contractual inter-municipal cooperation starting from around 15,000 to 25,000 inhabitants. In this case the role of the WMC is limited to organisational and competence-related functions only. A full-scale shift from municipal administration to WMC-based administration including the take-over of the customer service of the OWCS and management of the public waste services (waste stations, domestic hazardous waste collection, databases and registers, awareness raising activities) becomes cost-effective starting from around 100,000 to 125,000 inhabitants. The full-scale form of cooperation and implementation of

the advanced OWCS enables to integrate most of the public waste management costs into OWCS fees, which is supported by the polluter-pays principle.

An optimal size of a waste collection district should be determined by the estimation that the minimal size of the waste collection district provides the fill-up of the refuse collection vehicle in one collection route, which is around 20,000 to 30,000 inhabitants. A new tender evaluation model was worked out both for the regular and advanced OWCS. The main points of the new model are separation of the different stages of the service (collection, treatment and administration), and basing on the actual turnover, meaning winner is the tenderer who takes the least amount of money from the waste holders wallet. Separation of different stages of the OWCS gives a fair basis for the formation of the waste collection fees.

The subject of source sorting, particularly separation of bio-waste and paper waste from the mixed municipal waste, is actual due to the restrictions on landfilling and recycling targets arising from legislation. Although the waste hierarchy sets a clear order of priority on the treatment operations, in some conditions – in this case rural municipalities – following the waste hierarchy may not be environmentally viable nor economically feasible. The main questions regarding carbon footprint arising from separate collection of bio-waste and paper waste were: 1) do the CO_2 emissions from transportation cancel out the CO_2 savings arising from paper recycling; and 2) is the transportation of the bio-waste justified in case aerobic composting instead of home composting if expressed in CO_2 emissions. In the current research the approach of potential service volume of bio-waste and paper waste was applied in which the volume of service was calculated basing on the actual number of buildings with 10 or more dwellings. This approach gives an equal and adequate base to assess the feasibility of the service. According to the results of current research, the source sorting and central collection of bio-waste is not economically feasible nor environmentally viable in the majority of the Estonian municipalities. The alternative option to central collection of bio-waste is home composting or thermal or biological treatment of the mixed municipal waste. As to the central collection of source sorted paper waste, as long as the carbon emissions from the transportation do not annul the carbon savings from paper recycling, and the service is economically feasible, the separate collection of paper waste should be set up in village centres and towns.

The tool does not attempt to present precise economical features, a business plan, nor environmental report of the observed waste management model. Neither replaces the tool any LCA model. The tool aims to assess: 1) the economic feasibility and the improvement of the administrative efficiency arising from the inter-municipal cooperation; 2) the economic and environmental feasibility of central collection of source sorted bio-waste and paper; and 3) configure a fair tender evaluation model for the OWCS public procurement, either for the classic or advanced form. It is a simplified model which considers only the main indicators, leaving rest of the variables aside by ceteris paribus principle. The tool is applicable for any single municipality or a bunch of municipalities aiming to cooperate. The subject has not been researched from these aspects as a whole before.

KOKKUVÕTE

„Hajaasustusala jäätmehooldusmudeli majandusliku ja keskkonnamõju integreeritud hindamine ning mudeli optimeerimine Eestis Harjumaa omavalitsuste näitel"

Doktoritöö eesmärgiks oli välja töötada majanduslikult ja keskkonnakaitseliselt optimaalne olmejäätmete kogumise ja käitluse mudel hajaasustusega kohalike omavalitsuste jaoks. Uurimistöö hõlmas olmejäätmete käitluse majanduslike, sotsiaalsete ja keskkonnamõjude ning jäätmehooldusalase haldussuutlikkuse hinnangut Harju maakonna kohalikes omavalitsustes, samuti liigiti kogutud biojäätmete ja vanapaberi tsentraalse kogumise majanduslikku ja keskkonnakaitselist otstarbekust ning jäätmeveo logistika optimeerimist piiriüleste jäätmeveo piirkondade moodustamise läbi.

Uurimustöö rakendusliku osana koostati Exceli-põhine tööriist nelja näidis-omavalitsuse baasil. Tööriista peamine uuenduslikkus seisneb sisendinfo lihtsuses ja kättesaadavuses. Sisendinfona kasutati elanike arvu, haldusterritooriumide suurust, jäätmetekkeinfot ja teedevõrgustiku pikkust – kõik need andmed on saadaval avalikes registrites. Lisaks rakendati modelleerimisel korraldatud jäätmeveo lepingute ja jäätmevaldajate registrite andmeid, mis on olemas kohalike omavalitsustel. Tööriist koostati üheksal erineval leheküljel, mis järjestikku sisustati sisendandmeid töötlevate valemitega. Erinevatel lehekülgedel arvutati välja korraldatud jäätmeveo teenuse maht ja käibed, liigiti kogutud biojäätmete ja vanapaberi veoteenuse potentsiaal ning jäätmeveo reaalsed transpordikulud, hinnati biojäätmete ja vanapaberi liigiti kogumisega kaasnevat süsinikuemissioone ning töötati välja korraldatud jäätmeveo hankemudelid kahe erineva projektistsenaariumi jaoks. Lõpptulemused esitati kokkuvõtvalt viimasel lehel.

Omavalitsuste vahelisest koostööst tulenevad sotsiaalmajanduslikud eelised on ilmselged olenemata koostöösse haaratud omavalitsuste või neis resideeruvate elanike arvust. Siiski oleneb koostöö vorm ja selle efektiivsus mastaabist. Teatud kommunaalteenuste remunitsipaliseerimine on Euroopas üks hiljutisi trende ning viimased uuringud näitavad, et pole erilist vahet munitsipaal- või erasektori jäätmeveo teenuse osutaja efektiivsuses kui säilib konkurents. Tööriistaga modelleerimine näitas, et eraldi koostööorganisatsiooni loomine on otstarbekas alates umbes 15-25 tuhandest elanikust. Sel juhul piirduvad jäätmekeskuse funktsioonid administratiivse ja kompetentsipõhiste ülesannetega. Jäätmehooldus-ülesannete, sealhulgas ka korraldatud jäätmeveo klienditeeninduse ja avalike jäätmehooldusteenuste (jäätmejaamade ja avalike kogumispunktide opereerimine, kodumajapidamises tekkivate ohtlike jäätmete kogumine, jäätmeteavitustegevus, andmebaaside pidamine) täies ulatuses omavalitsuselt jäätmekeskusele delegeerimine on tasuv alates 100-125 tuhandest elanikust. Täismahuline koostöövorm ja korraldatud jäätmeveo klienditeeninduse ülevõtmine võimaldab saastaja-maksab printsiibi rakendamist läbi avalike jäätmehooldusteenuste kulude integreerimise jäätmeveo teenustasudesse.

Jäätmeveopiirkonna optimaalse suurus tuleks määrata selle arvestusega, et jäätmeveok saab ühe veoringiga täis, mis tähendab ligikaudu 20-30 tuhat elanikku. Uurimistöö raames töötati välja uus jäätmeveo hanke pakkumuste hindamismudel nii üheosalise kui ka kaheosalise hankemudeli jaoks. Uue hankemudeli põhiline mõte seisneb jäätmeveo teenuse üksikute osade (kogumine ja vedu, käitlemine, administreerimine) lahutamises ja käibepõhises hindamises, st võidab see pakkuja, kelle aastane kogukäive on väikseim, teisisõnu, kes jäätmevaldaja rahakotist kõige vähem raha välja võtab. Teenuse üksikute osade eraldamine annab objektiivsed ja õiglased alused jäätmeveo teenustasude kujunemisele.

Jäätmete liigiti kogumise, iseäranis biojäätmete ja vanapaberi eraldamine segaolmejäätmetest, on aktuaalne tänu seadusandlusest tulenevatele piirangutele jäätmete ladestamisele ja taaskasutusele seatud sihtarvudele. Kuigi jäätmehierarhia sätestab selge eelisjärjekorra töötlemistoimingutele, võib mõnel juhul – antud juhul maapiirkonnas – jäätmehierarhia järgimine osutuda keskkonnakaitseliselt ebamõistlikuks ja majanduslikult ja mittetasuvaks. Biojäätmete ja vanapaberi liigiti kogumisest tulenevate süsinikuemissioonide puhul on põhiküsimusteks: 1) kas transpordist tulenevad CO_2 emissioonid nullivad vanapaberi taaskasutusest saavutatud CO_2 säästud; ja 2) kas biojäätmete transport nende tsentraalseks aeroobseks kompostimiseks kodukompostimise asemel on õigustatud süsinikuemissioonides väljendatuna. Käesolevas uurimistöös kasutati potentsiaalse teenusemahu põhist lähenemist, milles teenuse maht arvutati välja 10- ja enama korteritega majade alusel. Selline lähenemine tagab adekvaatse ja võrdse aluse teenuse mahu ja tasuvuse hindamiseks. Töö tulemusena ilmnes, et liigiti kogutud bio-jäätmete tsentraalne kogumine ja aeroobne kompostimine ei ole keskkonnakaitseliselt ega majanduslikult otstarbekas ega tasuv enamuses Eesti omavalitsustes. Alternatiiviks on biojäätmete tekkekohal kompostimine või segaolmejäätmete termiline töötlemine. Vanapaberi tsentraalset kogumist, seni kui transpordist lähtuvad süsinikuemisioonid ei nulli taaskasutusest saavutatud süsinikusäästu ja teenus on majanduslikult tasuv, tuleks külakeskustes ja väikelinnades siiski rakendada.

Väljatöötatud tööriist ei pretendeeri vaadeldud jäätmehooldusmudeli täpsete majanduslike arvutuste, äriplaani või keskkonnaaruande esitamisele. Samuti ei asenda see tööriist olelustsükli hinnangu meetodit. Tööriista eesmärgiks on: 1) hinnata omavalitsuste vahelisest koostööst saavutatavat haldusvõimekuse paranemist ja majanduslikku tasuvust; 2) liigiti kogutud biojäätmete ja vanapaberi tsentraalse kogumise ja käitlemise keskkonnakatselist ja majanduslikku tasuvust; ja 3) luua läbipaistev hindamismudel korraldatud jäätmeveo hangetele, nii üheosalisele kui ka kaheosalisele mudelile. Tööriist võimaldab luua ja analüüsida lihtsustatud mudelit, mis arvestab üksnes kõige olulisemaid indikaatoreid, jättes ülejäänud *ceteris paribus* põhimõttel kõrvale. Mudel on rakendatav ükskõik millisele üksikule omavalitsusele või omavalitsuste grupile, kes soovivad teha koostööd. Teemat pole Eestis varem ülalnimetatud aspektidest käsitletud.

APPENDIX I ORIGINAL PUBLICATIONS

PAPER I

Kivimägi, J. 2011. A descriptive analysis of post-closedown environmental monitoring and maintenance of the Pääsküla landfill. *Management of Environmental Quality: An International Journal*, 22(6). 769 – 786

A descriptive analysis of post-closedown environmental monitoring and maintenance of the Pääsküla landfill

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Abstract

Purpose – The aim of this paper is to investigate changes in the environmental state of Pääsküla landfill in the post-closedown period, especially changes in the soil and groundwater quality, composition of leachate water and air quality, and to analyse the effects of the works carried out and the measures implemented during the closing down of the Pääsküla landfill on the surrounding environment.
Design/methodology/approach – The study is based on the official environmental monitoring reports (EERC 2005-2009) combined with the practical work experience and observations of the author on the landfill (Kivimägi 2007-2010).
Findings – The study reveals that the most evident changes, which have taken place in the environmental state in the Pääsküla landfill were those in the quality of surface water. Remarkable improvement of the water quality of the Pääsküla river was detected after installation of the vinyl pile wall around the landfill body. After capping of the landfill a drop in the content of methane in landfill gas was detected as well decrease of total gas production in the landfill.
Practical implications – The conclusions justify the efforts made in the course of closing down works of the Pääsküla landfill and the chosen technical solutions. It is necessary to continue the environmental monitoring of the landfill leachate water, ground water and surface water as well as monitoring of air quality and subsidences on the landfill.
Originality/value – The paper provides detailed overview of the post-closedown environmental monitoring and maintenance activities in the landfill as well as progress in the state of environment regarding the measures taken in order to decrease the negative environmental impact of the landfill. The experience of closing down the landfill can be used for similar projects, especially the impacts of capping the landfill on the methane production and installation of the protection wall and leachate collection drainage around the landfill on the suface water.
Keywords – EU ISPA fund, closing down landfill, leachate water, landfill gas, landfill irrigation, environmental impact, landfill monitoring, maintenance of landfill, groundwater, soil water, surface water, air quality.
Paper type – research paper.

1 Introduction. Background

The Pääsküla landfill is a former landfill in Tallinn, which was closed down in 2003-2006. The landfill was established in 1974 as a temporary dumping site for municipal waste, however at the moment of closing down in 2003 its volume had grown to 4.5 million cubic metres and mass to 3,6 million tons, its relative height up to 29 metres and its area reached nearly 30 hectares. It was the largest municipal waste landfill in Estonia with the circumference of 1.8 kilometres. Surrounded by the Pääsküla bog and situated only 200 metres from the Pääsküla river and detached houses area it carried a potential threat to ambient environment (ground water, surface water, air *etc.*) as well as to the health of people living nearby [Final Report, 2008].
The landfill was closed down during the period of 2003 to 2006 within ISPA (The Instrument for Structural Policies for Pre-accession) project. The ISPA project [Regio-ISPA, 2004] Tallinn Waste Management, Phase II – closing down Pääsküla landfill was preceded by another important ISPA project: Tallinn Waste Management – Phase I concerned two separate investments within the ongoing establishment of the new landfill and the new waste treatment plant:

- construction of an access road from Peterburi Road to the landfill site (5.5 km)
- connecting the landfill area with the sewage system of Tallinn City by means of a new pipeline (11 km) and pumping stations thus providing for the treatment of the leachate from the landfill.

In addition, Tallinn Waste Management – Phase I included two components for which no ISPA assistance was required. Those two components, for a total investment cost of approximately € 37,4 million, were the construction of the first phase of new landfill and the construction of the first part of the infiltration water system [ISPA, 2000].

The ISPA project Tallinn Waste Management, Phase II – closing down the Pääsküla landfill was an important stage of Tallinn waste management, which preparations were started already in early 1990ties. The landfill had to be closed down because it did not meet the European Union (EU) requirements for landfills. Objectives of the projects were to minimize the environmental impacts in a long perspective against main hazards as contamination of groundwater and surface water, landfill gas leakage, health hazards to neighbourhood dwellings and nuisance like offensive smell, fly trash, gulls and other birds and rodents. The total cost of the Tallinn Waste Management, Phase II project was € 9 512 720 excluding V.A.T. out of which 75% was financed by EU ISPA fund and 25% by Tallinn City Government. Including V.A.T. 18% which was paid by the Tallinn City Government, the cost of the project was € 11 225 009 (175 633 228 EEK) [Final Report, 2008].

The project lasted from 2003 to the end of 2008. The main closing down works of the landfill were executed during 2003-2006 and additional works executed during 2007-2008. The scope of main works for closing down the landfill included installation of vinyl pile wall around the landfill, construction of leachate water collection system and irrigation system, construction of landfill gas collection system (7 km of pipes, three regulation stations, a compressor and a gas burner), capping of the landfill body with bentonite geomat and installation of landfill monitoring system. The duration of the project was prolonged till the end of 2008 and during the last 2 years the supervisory of construction works was carried out, as well as construction of the public waste station for recyclables and cleaning up of the sanitary zone of 300 metres from the landfill perimeter.

The maintenance and monitoring of the former landfill will continue for the next two decades, till 2026, since the monitoring period of the landfill is set for 30 years from the closedown of the landfill. Current sanitation activities include environmental monitoring (air quality, leachate water quality, surface water quality, groundwater quality, subsidences), maintenance of the slopes, waste water treatment and collection of landfill gas. Landfill gas has been collected already since 1994 when the first 10 km of collection pipes and a collection station were installed on working landfill, thus together with additional pipes, there are approximately 17 kilometres of gas collection pipes in the landfill. The collected landfill gas is used as fuel for two combined heat and power (CHP) systems, selling heat and power to local energy company. The territory of the landfill is guarded and closed to the public, except the public waste station located at the entrance of the landfill. Environmental monitoring of the closed down landfill has been carried out since 2005 by the Central Lab of the Estonian Environmental Research Centre (EERC) and the reports show remarkable improvements of surface water in the river [Kivimägi, 2007-2010].

As Terry Brisco exemplified in his article in the European Commission's book on regional policy *Investing in our regions, investing in the future*: „Yesterday's waste is today's energy. A huge landfill site close to Tallinn has been closed and cleaned up. Once an eyesore and source of pollution, the site was shut down in 2003 and underwent significant work to tackle various environmental and health hazards. It today produces valuable biogas, heat and power for local energy companies. The three-year clean-up led to major improvements locally, among them an odour-free area, better water quality, and the return of certain wild animals. City authorities hope to turn the area into a recreational zone." [Brisco, 2010]

2 Materials and methods

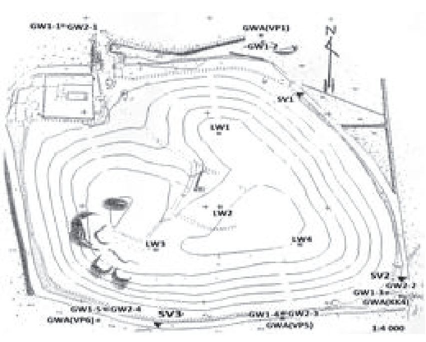
The post-closedown environmental monitoring has been carried out in the Pääsküla landfill since its closedown in 2003. The observed period of environmental monitoring in the current paper is 2005-2009, except subsidences, which monitoring data was available only for the period of 2007-2008. The sampling points for groundwater, surface water and leachate monitoring are shown on the Figures 1 and Figure 2, subsidences monitoring benchmarks and air quality monitoring points are shown on Figures 3 and 4. The measurements and sampling for the environmental monitoring were carried out by the Estonian Environmental Research Centre (EERC). The biogas collection data has been recorded by the automatic monitoring system, integrated in the biogas collection system, particularly in the gas compressor station and monthly reported by the gas collection system operator [Kivimägi, 2007-2010].

TABLE 1 **Methods used for the water analysis [EERC, 2008]**

Indicator	Method (or code*)	Short description of the methods
Oxygen dissolved in the water	O2_DF*	Electro-chemical sensor in exterior conditions
Water temperature	T_WT*	Temperature sensor in exterior conditions
Electrical conductivity	EVS-EN ISO 11905-1	In exterior conditions, in regard to 25°C
pH	ISO 10523	Potentiometric measurement with a glass electrode in exterior conditions or in the laboratory at +20° C
BOD_7	ISO 5815-1,2	Oxygen demand of an unfiltered sample with the electrochemical measurement of O_2
COD	ISO 6060	The bichromatic oxygen demand of an unfiltered sample, the final measurement with the help of titration
Ammonium-nitrogen	ISO 7150-1	Spectrometric measurement of an unfiltered sample
Total nitrogen	EVS-EN ISO 11905-1	With an automatic analyzer
Total phosphorus	EVS-EN ISO 6878	Spectrometric measurement of an unfiltered sample
Chloride	ISO 9297	Titration of an unfiltered sample or measurement with ionchromatography
Cd	EVS-EN 15586	Atom absorption of an unfiltered sample in a graphite oven
	EVS-EN ISO 11885	Inductively coupled plasma optical emission spectrometry (ICP-OES)
Hg	EVS-EN 1483, ISO 5666	Atom absorption of an unfiltered sample by the cold steam method
Pb	EVS-EN 15586	Atom absorption of an unfiltered sample in a graphite oven
	EVS-EN ISO 11885	Inductively coupled plasma optical emission spectrometry (ICP-OES)
Zn	EVS-EN 15586	Atom absorption of an unfiltered sample in a flame
	EVS-EN ISO 11885	Inductively coupled plasma optical emission spectrometry (ICP-OES)

The list of the indicators to be analyzed in the samples was specified by the initial objectives for the environmental monitoring of the landfill. The laboratory analyses of the water were processed at the Marja Street Laboratory of the EERC, using internationally recognized methods. The outdoor and indoor measurement methods are described in Table 1. The method codes shown in the table are the codes used in the Nordic countries for indicating analysis methods. The Environmental Research Centre has received accreditation from the Estonian and German accreditation centres regarding all the given measurement methods, and the results are accepted by the European Union and elsewhere [EERC, 2008].

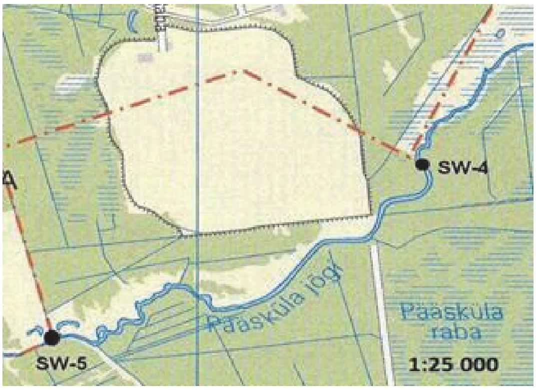
2.1 Groundwater monitoring



As a rule, the samples from the soil water monitoring wells (GW 2-1 to 2-4) were taken from the pumping hose after emptying; from the soil water wells (GW 1-1 to 1-5); samples were taken with a bailer after discharge pumping, on the same or following day. The monitoring results are presented in brief in the next chapter separately for the ground water in the Ordovician and Quaternary water layers, and the results are illustrated with diagrams. Hereafter the term "soil water" will be used for the Quaternary ground water and the term "bottom ground water" for the Ordovician ground water. Samples were taken once a quarter during 2005-2008 and twice a year on 2009 [EERC 2009].

FIGURE 1 **Groundwater, surface water and leachate monitoring wells [Kivimägi, 2007-2010]**

2.2 Monitoring of surface water



Surface water samples were taken once a quarter during 2005-2008 and twice a year on 2009 from the Pääsküla River upstream and downstream (SW-4 and SW-5 respectively on Figure 2) of the landfill and from three points in the circular landfill ditch (SV1, SV2 and SV3 on Figure 1). An ordinary plastic sampling container on the end of a telescopic rod was used for sampling.

FIGURE 2 **Surface water sampling sites [EERC, 2008]**

2.3 Leachate monitoring

Leachate water is collected by drainage pipes within the vinyl pile wall, surrounding the landfill and pumped up to the hill into the irrigation system, in order to contribute to the biogas formation in the landfill body. Thus the leachate water is in continuous circulation [Kivimägi, 2007-2010].

Leachate samples were taken once a quarter during 2005-2008 and twice a year on 2009. The location of the monitoring wells is shown on Figure 1 as LW1, LW2, LW3 and LW4. The coordinates and depths of the wells are shown in Table 2. Samples from the leachate were taken on with disposable bailer. On 2009 the 1st half of the year leachate samples were taken from 3 wells out of 4 because of collapse of the well LW 2. The well LW 3 was still passable then, however both wells were tamped and new monitoring wells next to the closed ones were installed in July 2009. The numbers of wells remained the same.

TABLE 2 **Coordinates and depths of the leachate wells [EERC, 2008]**

Well	X (north)	Y (east)	Top edge of pipe (a.s.l.), m	Depth of the well, m	Length of the open part, m
LW 1	065-80-467	005-36-922	63.90	24,84	16,94
LW 2	065-80-317	005-36-924	65.96	29,38	21
LW 3	065-80-226	005-36-818	64.25	26,59	21
LW 4	065-80-245	005-37-043	66.94	30,26	20,93

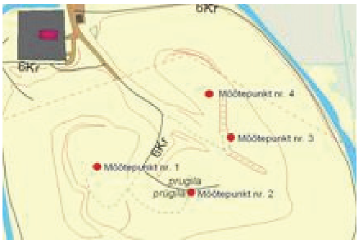
2.4 Monitoring of subsidences

The available data regarding subsidences involves only period of 2007-2008.

The absolute height was based on PP. 5364, H=37,214, height in the Baltic system of 1977 year. For the surveying of heights were made vertical travers between benchmarks PP.5364, BM1, BM2, BM3, BM4, BM5, BM10, BM11. Based on abovementioned benchmarks once in the quarter, the benchmarks BM6, BM7, BM8, BM9, BM12, BM13, BM14, BM15 were surveyed. Based on the measurements the scheme of benchmarks was drawn (Figure 3) and after every survey the table of data was compiled [EERC, 2008].

FIGURE 3 **Location of benchmarks [EERC, 2008 ©Hades Geodeesia]**

2.5 Air quality monitoring



The indicative measurements of methane, sulphur dioxide, carbon monoxide, carbon dioxide, hydrogen sulphide and oxygen were carried out with a special landfill Gas Analyzer GA 2000. Four measuring points were chosen on the territory of the Pääsküla landfill, locations of measuring points are shown on the Figure 4.

FIGURE 4 **Air quality monitoring sites, red dots on the map [EERC, 2009]**

Concentrations of emission gases were measured with landfill Gas Analyzer GA 2000. For determining the concentration of methane and carbon dioxide, a special sampling bell jar was placed to the depth of approximately 10 cm into the ground in the point of measurement, the edges of the bell jar were covered with soil. In order to determine the concentration of gases emitted from the landfill soil and collected under the bell jar, the air was sucked through a silicone pipe into the analyser, which instantly showed the concentrations of methane and carbon dioxide in the air sample. The concentrations of methane and carbon dioxide in the air sample were measured approximately 1 hour after placing the bell jar onto the ground. The measurements were also taken from four gas pipes. To collect gases, perforated pipes were placed in the deeper layers of the landfill (Figure 5). The pipes were perforated and placed to the layer in the depth of 80 cm onto the cover foil and surrounded by crushed stone. A silicone pipe was placed into a gas pipe and air was sucked through the silicone pipe into the landfill gas analyser, which instantly showed the concentrations of the pollutants in the gas pipe [EERC, 2008].

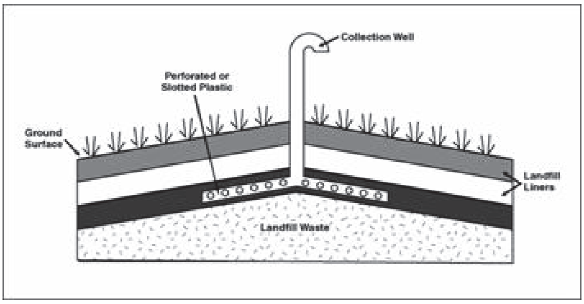


FIGURE 5 **Landfill gas collection well [EERC, 2009]**

2.6 Biogas collection

The biogas production of the landfill is measured and registered in automatic system which counts the amounts of landfill gas, collected and utilised for electricity and heat production. The monthly reports of the biogas production were made by the biogas collection system operator TERTS Ltd (AS TERTS). First part of the biogas collection system was installed and launched in 1994, covering 25 hectares and 10 kilometres with its length of the pipes. The second part of biogas collection system was constructed and installed in the framework of the closing-down project, involving 7 kilometres of collection pipes, three regulation stations, a torch incinerator and the compressor station with gas production monitoring system. Both collection systems are built horizontally [Kivimägi, 2007-2010].

Usually preference is given to vertical collection wells. Vertical gas collection wells are perforated plastic pipes with the diameter of 4 to 8 inches, which are installed in the borehole at the depth of 60-80% of the total height of the waste bed, but not closer than 3-3,5 metres from the bottom layer. When installing supplementary collection pipes, it should be remembered not to install them in the areas where asbestos or other mineral (inert) waste has been disposed. Considering the condition of the Pääsküla landfill – lack of monitoring data (or data that show inefficiency of existing vertical monitoring wells), and possible evidence that a lot of inert wastes have been dumped to the bottom layers of landfill – the preference of vertical collection system is not a must [Ruut, 2003].

The biogas production presented in the next chapter shows a constant trend of decrease, which, considering the main factors – the landfill is capped, which results in lack of oxygen, and the amount of organic waste reduced by continuous decay processes – is expected and normal [Kivimägi, 2007-2010].

3 Results and discussion

The main results and conclusions of the environmental monitoring are presented below. The Pääsküla landfill is the biggest closed-down solid waste landfill in Estonia, which undergoes detailed and systematic environmental monitoring on such a scale. It is also the only landfill in Estonia where the leachate water is used for irrigation of the landfill body in order to contribute to the landfill gas production. Since the period of environmental monitoring observed in the current paper is only 5 years, the occurring trends may be random in some cases and the long term tendencies cannot be predicted, however the overall improvement in the ambient environment of the landfill is obvious.

3.1 Groundwater

Regarding the conclusions from the EERC monitoring report of 2007-2008, the impact of the landfill on the samples taken from wells within the circular ditch is demonstrated by the increased content of chlorides, nitrogen and phosphorus compounds, compared to the samples taken from the wells outside the circular ditch. In the soil water of all the monitoring wells, located inside the circular ditch, a sudden increase of compounds has been noticed, which indicate pollution in the spring during that period. The pH of the soil water is correlated to the water level – it is at its lowest level when the water level is at the minimum and vice versa. Changes in the level of soil water are reflected in the level of ground water at the minimum (summer) and maximum (spring) periods. There is a clear **correlation** between the temperature of the soil water and the ambient air, since the water layer is not far from the surface. After the completion of landfill decreasing of some characteristics has been noticed like COD, content of ammonia and total nitrogen in the water of most polluted wells, and as quite different tendency the clear increase of the content of chlorides in the GW1-5 (what is from wells inside circular ditch with cleanest water) [EERC, 2008].

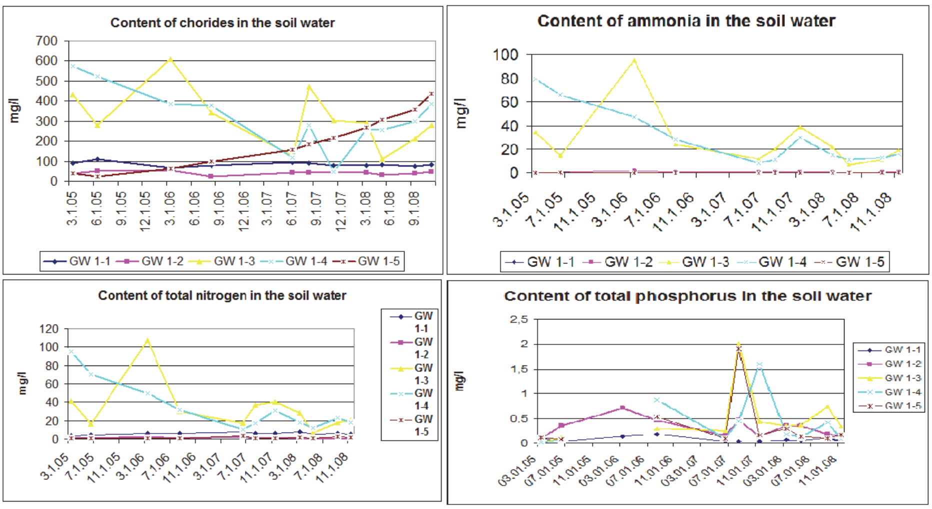


FIGURE 6 **Monitoring results of soil water [EERC, 2008]**

As to the bottom ground water in the bedrock, it is not possible to observe any clearly defined trends regarding the chemical composition of the bottom ground water, except the ambiguous decrease of total nitrogen in the water of the well GW2-3. Out of heavy metals in both the surface and bottom ground water, the mercury content is below the laboratory's detection limit, and the cadmium content is also mostly below or close to the laboratory's detection limit [EERC, 2008].
Since all the trends mentioned above for the monitoring period 2005-2008 were continuingly followed in the measurements results in 2009, the main conclusions from the previous period can be extrapolated and prolonged till the end of 2009 [Kivimägi, 2007-2010].

3.2 Surface water

For decades the Pääsküla landfill's leachate has been collected into the circular ditch. In the course of the completion work, the leachate was directed into the Tallinn sewer system. Therefore, it is interesting to find out when the water in the circular ditch achieves the quality that will allow us to direct it into the Pääsküla River. The quality of the water in the circular ditch started to improve drastically at the end of 2005, after the cleaning of the ditch bottom and the installation of a geotextile screen and drainage system, which prevented the leachate from subsequently infiltrating to the circular ditch [EERC, 2008].

Total nitrogen content in the water exceeded the limits to the greatest extent. Almost all the annual averages exceeded the norms. At the same time, Illustration 1 on Figure 7 shows that in recent years, the water quality of the circular ditch has improved considerably. The reduction in nitrogen content already started in 2001. A significant drop in the nitrogen content in points SV1 and SV2 has also taken place since the end of the 2005. Previously, the situation in these sections of the circular ditch had been very bad. This could have been also caused by the construction work, during which the bottom of the ditch was cleaned, and unavoidably, pollutant-rich sediments were swirled up. Nitrogen is the most typical pollution component in landfill leachate. It develops during waste decay and is present in water primarily in the form of ammonium compounds. The content of the latter in sewage is not regulated by the law, but because of a drop in the concentrations of NH_4^+, N_{tot} will also drop. From Illustration 2 on Figure 7, one can see that a sudden drop in the ammonium content of the circular ditch water has taken place during the last few years [EERC, 2008].

Phosphorus compounds can also be found in the leachate of landfills, but there are significantly less of them there than, for instance, in the wastewater of typical settlements. Therefore, they are not considered characteristic of landfills and Illustration 3 Figure 7 also shows that the average phosphorus content of the ditch water never exceeded the norm of 1 mg/l. Nevertheless, there has sometimes been too much phosphorus in individual analyses. Apparently, the situation will improve in the future, once vegetation starts to use the fertilizers in the sediment in the bottom of the ditch [EERC, 2008].

Large amounts of organic matter can be found among the waste, which in the course of decaying ends up in the leachate. COD assesses the content of almost all organic matter, i.e. that, which decays easily and that, which decays with more difficulty. The upper limit for this is 125 mg/l. From the Illustration 4 on Figure 7 we can see that these limits have been exceeded in the circular ditch water, although an improvement tendency can be clearly noticed [EERC, 2008].

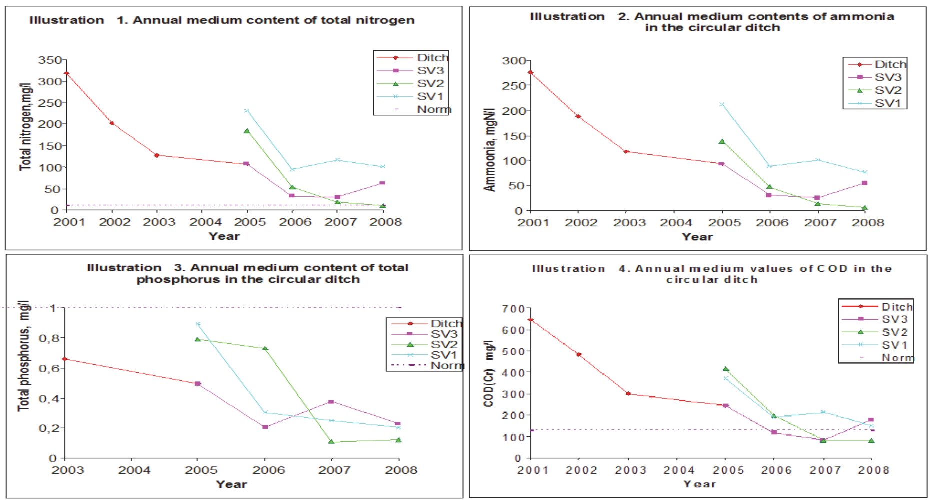


FIGURE 7 **Monitoring results of surface water [EERC, 2008]**

In the course of the completion operations for the landfill, remarkable improvement has also taken place in the water quality of the Pääsküla River (Figure 8). The values of the pollution indicators in the samples taken downstream the landfill have become quite close to those of the samples taken upstream the landfill (not influenced by the landfill). Under unfavourable conditions, rather large amounts of pollutants may be carried into the river by Tallinn's stormwater ditches that can influence the quality of water even more than the landfill before its closure [EERC, 2008].

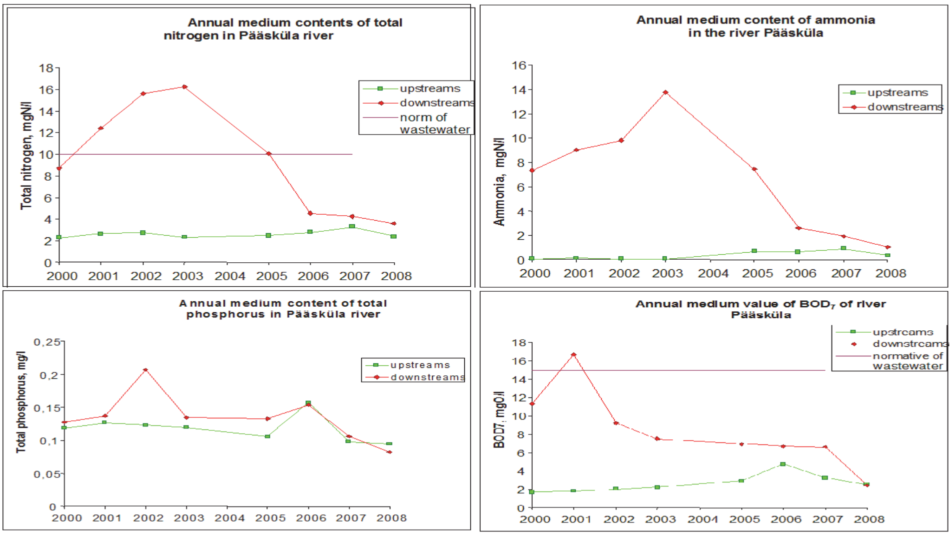


FIGURE 8 **Monitoring results of Pääsküla river [EERC, 2008]**

3.3 Leachate

The main results of the leachate monitoring are presented on Figure 9 and Tables 3 and 4.

In addition to the leachate monitoring carried out by EERC, since July 2007 when the leachate collection system was connected to the central sewage system, the leachate samples have also been taken by the wastewater treatment company Tallinna Vesi Ltd (AS Tallinna Vesi) 4 times a year. From all the indicators measured in the samples (temperature, pH, floating substances, hydrocarbons, BOD_7, P_{tot}, N_{tot} and polar substances) total nitrogen has exceeded the limit values set on wastewater during the whole period till January, 2010 and biological oxygen demand exceeded the limit values episodically in the abovementioned period (Table 3 and Figure 9) [Kivimägi, 2007-2010].

TABLE 3 **Leachate samples taken by Tallinna Vesi Ltd [Kivimägi, 2007-2010]**

Leachate analysis Raba 20		2007				2008				2009				2010
mg/l	Limit value	4.07.2007	13.08.2007	28.09.2007	11.12.2007	17.03.2008	9.07.2008	19.09.2008	8.12.2008	11.03.2009	2.06.2009	30.09.2009	13.10.2009	13.01.2010
weather		Dry	Dry	Dry	Rain	Melt	Dry	Dry	Dry	Melt	Dry	Rain	Cloudy	Snow
ambient temperature		26 C	33 C	13 C	5 C	1 C	21 C	8 C	- 2 C	1 C	21 C	5 C	3 C	- 3 C
pH	**6,5-8,5**	7,5	7,4	7,3	7,1	7,4	7,3	7,3	7,2	7,2	6,9	7	7,1	7,3
floating substanc	**500**	88	54	44	260	84	120	104	34	190	88	80	68	112
BOD7	**375**	115	129	95	240	220	190	850	490	425	600	200	130	450
HC	**5,5**	2	2	2	2	2	2	2	2	2	2	8,5	2	2
P tot	**15**	4,45	5,22	4,33	3,14	3,8	6,39	4,18	3,48	5,73	6,79	5,69	1,13	3,66
N tot	**125**	916	851	718	680	790	1195	974	710	735	1117	930	253	633
polar substances	**50**	4,8		4,5	9	8,2	9,5	9,8	8,2	8,5	10,3	14,5	6,8	5,8

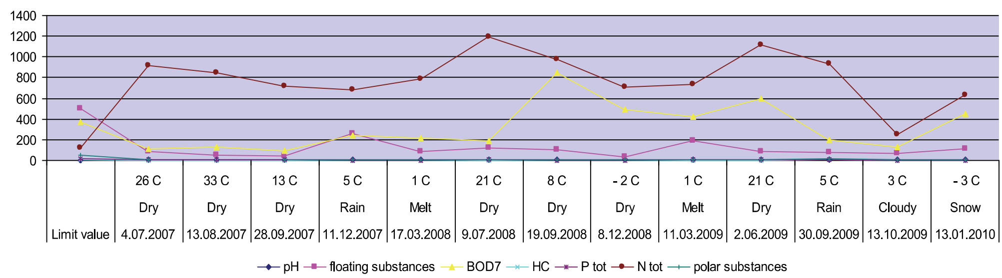


FIGURE 9 **Leachate samples taken by Tallinna Vesi Ltd [EERC, 2008]**

In the chemical composition of leachate circulating in the body of landfill it is not possible to observe any clear tendencies, and changes in the leachate contents may vary on large scale. In the leachate samples, ammonium formed 94-98% of the nitrogen compounds. In the chemical composition two possible tendencies become apparent: it is possible to observe the tendency of the increasing BOD_7 (except LW1, covered by layer of oil) in the leachate, and on the contrary, the tendency to decreasing of COD can be observed. The temperature of leachate is somewhat correlated to the ambient air temperature. In the leachate from the well LW4 the decrease of concentration of heavy metals also becomes apparent. It doesn't appear so clearly in case of the other wells [EERC, 2008].

No general correlation between the changes in temperature, pH, biological and chemical oxygen demand nor contents of nitrogen and phosphorus can be drawn neither in respect of wells nor years. The temperature of leachate fluctuates between 17 °C and 39,9 °C, being averagely 31,8 °C. The pH fluctuates between 6,7 and 8,7, being averagely 7,7. Both the average temperature and the minimum and maximum temperatures were the highest in the well LW4, where also the indicators of BOD7, nitrogen and phosphorus were higher than in the other wells. This may point to the higher content of available organic materials in that area of the landfill which results in the higher activity of decay processes. Unfortunately, there is no available data about the landfill gas production and its methane content in this corner of the landfill, thus the hypothesis cannot be supported by the landfill gas collection results [Kivimägi, 2007-2010].

TABLE 4 **The monitoring results of leachate on the period of 2005-2009 [Kivimägi 2007-2010]**

Well, LW	Date	Temperature, °C	Ammonium, mg/l	Total nitrogen, mg/l	Total phosphorus, mg/l	pH	BOD7, mgO/l	CODCr, mgO/l
LW1	max	33,80	2370,00	2750,00	18,00	7,74	1900,00	7300,00
	min	17,00	506,00	526,00	2,80	6,66	130,00	1340,00
	average	30,23	1124,25	1247,63	9,92	7,25	511,56	3357,50
LW2	max	31,40	2945,00	3460,00	24,00	8,66	2000,00	3700,00
	min	17,50	667,00	885,00	7,00	7,43	75,00	1700,00
	average	28,63	1764,75	1922,81	14,25	7,70	481,56	3055,00
LW3	max	35,80	2360,00	2720,00	22,00	8,54	880,00	6800,00
	min	24,50	1030,00	1124,00	10,00	7,50	155,00	2650,00
	average	31,38	1570,65	1752,65	13,47	7,80	367,65	3581,18
LW4	max	39,80	3010,00	3490,00	25,00	8,37	2550,00	5900,00
	min	34,30	1630,00	1690,00	16,00	7,76	250,00	3500,00
	average	37,15	2291,60	2562,93	19,50	7,89	616,67	4708,67
2005	max	37,10	3010,00	3490,00	22,00	7,80	1900,00	5900,00
	min	17,00	1540,00	1640,00	12,00	7,43	75,00	3100,00
	average	29,99	2129,64	2339,14	15,71	7,62	404,64	4057,14
2006	max	39,70	2700,00	2780,00	24,00	8,08	610,00	5800,00
	min	24,50	600,00	602,00	3,60	7,35	130,00	2200,00
	average	33,59	1874,67	1960,47	15,01	7,75	356,33	3837,33
2007	max	39,80	2310,00	2900,00	25,00	7,91	840,00	5350,00
	min	27,10	506,00	526,00	2,80	6,81	230,00	1340,00
	average	33,08	1439,15	1666,62	13,14	7,51	463,46	3346,15
2008	max	38,40	2390,00	3180,00	20,00	8,66	2550,00	6800,00
	min	26,70	714,00	860,00	6,50	7,12	220,00	2500,00
	average	31,93	1573,94	1851,88	13,47	7,90	772,81	3387,50
2009	max	35,20	1800,00	1829,00	18,00	8,07	490,00	7300,00
	min	17,50	582,00	661,00	7,00	6,66	140,00	1700,00
	average	29,89	1111,71	1202,14	12,60	7,58	352,86	3714,29
total	max	39,80	3010,00	3490,00	25,00	8,66	2550,00	7300,00
	min	17,00	506,00	526,00	2,80	6,66	75,00	1340,00
	average	31,31	1666,26	1854,17	14,03	7,68	519,05	3665,67

3.4 Subsidences

The monitoring of subsidences shows that the body of landfill is mostly stabilised and steady. Some collapses reaching up to one meter took place within the construction period, however, after capping the monitoring confirms the steady status of the landfill body. Yet, two leachate sampling wells were squeezed due to the subsidence on some layers of the landfill in July, 2008. The wells were reconstructed in April, 2009. Within the observed period the maximum subsidences vary from 0.38 metres at the benchmark B5 to 0.03 metres at the benchmark B14 (Table 5) [Kivimägi, 2007-2010].

TABLE 5 **Subsidences 2007-2008 [Kivimägi, 2007-2010]**

Height, m	19.06.2007	24.09.2007	21.12.2007	31.03.2008	16.06.2008	18.09.2008	30.12.2008	Subsidence
BM 1	46,67	46,66	46,64	46,63	46,62	46,62	46,60	-0,06
BM 2	60,15	60,07	59,99	59,95	59,91			-0,24
BM 3	64,10	64,02	63,93	63,86	63,82	63,76	63,70	-0,41
BM 4	66,29	66,23	66,16	66,11	66,08	66,03	65,98	-0,31
BM 5	66,72	66,63	66,55	66,48	66,44	66,39	66,33	-0,38
BM 6	63,33	63,29	63,24	63,19	63,17	63,14	63,10	-0,24
BM 7	51,77	51,76	51,74	51,72	51,72	51,71	51,70	-0,07
BM 8	51,56	51,54	51,53	51,52	51,51	51,49	51,48	-0,09
BM 9	64,90	64,84	64,80	64,77	64,73	64,69	64,65	-0,25
BM 10	66,59	66,52	66,45	66,40	66,36	66,31	66,26	-0,33
BM 11	64,81	64,75	64,71	64,68	64,64	64,60	64,56	-0,25
BM 12	62,99	62,98	62,97	62,96	62,94	62,93	62,91	-0,07
BM 13	51,00	50,99	50,99	50,99	50,97	50,95	50,94	-0,06
BM 14	56,80	56,80	56,79	56,79	56,78	56,76	56,76	-0,03
BM 15	65,29	65,21	65,15	65,10	65,05	64,95	64,95	-0,33

3.5 Air quality and biogas production

According to the results of measurements (Table 6) there is no dissipation of H_2S and CO_2 from the capped landfill body to the atmosphere. The measured level of carbon dioxide refers to the fact, that in the near surface layer the oxidising processes are prevalent. Probably the methane that is generated in deeper anaerobic layers is consumed by methane consuming bacteria in the near surface layer. There is no significant pollution with methane or CO_2 [EERC, 2008].

TABLE 6 **Results of landfill gas monitoring [EERC, 2008-2009]**

Measured parameter	Date of measurments					
	13.07.2007	4.02.2008	22.05.2008	21.11.2008	27.05.2009	28.10.2009
CH_4, %	0	0	0	0,1	0	0
CO_2, %	0,1	0	0,1	0,1	0	0,1
O_2, %	19,8	20,1	19,9	20,6	20,8	19,8
H_2S, ppm	0	0	0	0	0	0
CO, ppm	0	0	0	0	1	0
BAL, %	79,9	79,7	79,9	79,2	79,3	80,1

The biogas production has shown a steady trend of decrease and has fluctuated from 749 495 Nm^3 in July 2005 as maximum down to 228 342 Nm^3 in July 2009 as minimum of the observed period [Tiidemann, 2005-2010]. Except a few additional and sudden drops in biogas production, the decreasing trend on Figure 10 is obvious and steady and not so dependant on the seasons but rather on the available organics for the degradation in the landfill and other processes like available moisture to the methane producing bacterias [Kivimägi, 2007-2010].

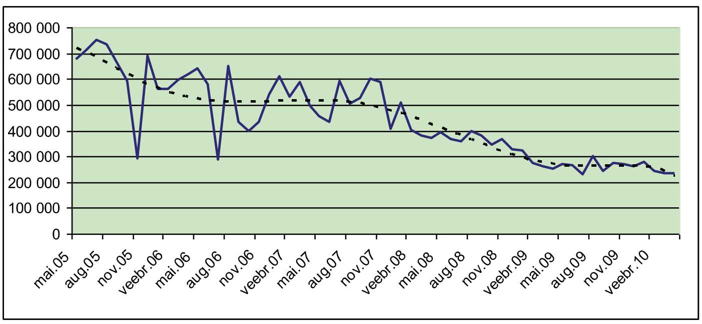


FIGURE 10 **Biogas production 2005-2010, Nm^3 [Kivimägi, 2007-2010]**

3.6 Sanitation and maintenance

The maintenance activities at the Pääsküla landfill involve cleaning up the stormwater ditches and cascades, mowing grass on the landfill slopes during the vegetation period from May to October and cleaning of the roads around the landfill and uphill to the biogas collection regulation stations and monitoring wells from snow during winter time**.** The area of the landfill is guarded by a contractor and is closed for public, except the waste station for recyclables at the foot of the landfill. The amounts of landfill leachate pumped to the central waste water treatment pipes have fluctuated from zero to 4.5 thousand cubic metres a month, depending both on season and precipitation as well as some factors still not known [Kivimägi, 2007-2010].
The expenses of sanitation of the landfill (maintenance, environmental monitoring, waste water treatment and guarding) are covered partly form the rental of the biogas collection system and mostly from the budget of city government. Within the years of 2007-2009 the average budget for sanitation and maintenance was around € 400 000, out of which almost a half represented the cost of leachate water treatment [Kivimägi, 2007-2010].
The main weakness of the technical solution of the project lies in the leachate water treatment and irrigation system. After few years of exploitation the pipes of the irrigation system tended to get congested with the sediments and no clean-up solutions were foreseen by the engineers, nor are they available on the market. The pipes of the irrigation were monitored by a robot-camera, which showed that the perforation of the pipes was mostly filled with mud and sediments of the leachate. The attempts to flush the pipes did not give the expected results and additional irrigation system had to be installed [Kivimägi, 2007-2010].

4 Conclusions

This study has revealed that the state of the ambient environment of the landfill has improved after the closedown and capping of the landfill, especially the quality of surface water, which carries a vital impact on the water quality of the Pääsküla river as well. The closedown works and sanitation activities decreased the negative environmental impact of the landfill remarkably. The completion of the closedown works on the landfill also lead to the decrease of the landfill gas production and its methane content. The conclusions are based on the environmental monitoring and reporting data from the period of 2005-2009.
As can be derived from the monitoring data, the content of chlorides, nitrogen and phosphorus compounds in soil water have increased within the circular ditch, compared to the samples taken from the wells outside the circular ditch. The increase in the pollutants inside the circular ditch can be caused by the precipitation which, mixed with leachate water permeated through the slopes, carried leachate pollutants into the circular ditch. The quality of the surface water in the circular ditch started to improve drastically after the installation of the geotextile screen and drainage system, which prevented the leachate from subsequently infiltrating into the circular ditch. The water quality of the Pääsküla river has improved remarkably after the installation of the screen as well. The content of the pollutants in the samples taken downstream the landfill has become quite close to the samples taken upstream the landfill, not influenced by the landfill. This proves that the landfill leachate polluted the river downstream the landfill and the measures taken during the closedown of the landfill have been justified. The total nitrogen content in leachate water has exceeded the limit values since the beginning of the monitoring period and do not show any clear trends of decrease. Since the leachate is continuously circulating in the landfill body, and thus washing out the pollutants from the layers of different wastes, the decrease in the pollutant content in the circulating leachate is not expected either.
After capping the landfill, a drop in landfill gas production was detected. The phenomenon apparently lies hidden in the lack of oxygen for the decay processes and the decreasing amounts of available organic materials to the degradation. The irrigation of the landfill body with the leachate water has not clearly proved to be efficient, however a delayed reverse correlation between the amounts of wastewater pumped to the central sewage system and the landfill gas production was detected, meaning that a month or two later the landfill gas production either increased or decreased, according to the amounts of leachate pumped back to the irrigation system or pumped to the central sewage network, out of the irrigation system. The quality of the ambient air has been within the limits of pollutants.
The advantages and disadvantages of the chosen technical solution of the project should be considered in the similar projects. As to the blocking of the leakage of the pollutants from the landfill to the ambient environment, the barrier wall and capping of the landfill have justified their use and can be highly suggested. On the contrary,

the leachate water treatment and irrigation system should be revised and improved if applied in any other similar project.
Beside the improvement of environmental conditions, the visible results of closing down the landfill are absence of offensive odour and nuisances like rodents, seagulls and other birds. The surrounding bog has developed it's recreational potential and the detached houses area nearby have gained in their value. The period of post-closing-down environmental monitoring and maintenance is set for the next 30 years, however it can be shortened if the environmental reports show sufficient improvements and the gas production has decreased down to environmentally safe level. One day in the future the former landfill body can become a recreational area with a magnificent panoramic view over the city of Tallinn.

FIGURE 11 **A view to the landfill, October 2006 [Kivimägi, 2007-2010]**

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PAPER II

Kivimägi, J., Loigu, E. 2013. The Environmental and Economic Feasibility of an Organised Waste Collection Scheme as a part of Integrated Waste Management System. *International Journal of Energy and Environment 2013*, vol 7, 178 – 187. ISSN: 2308-1007. North Atlantic University Union (NAUN).

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

Jana Kivimägi, Enn Loigu

***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 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.

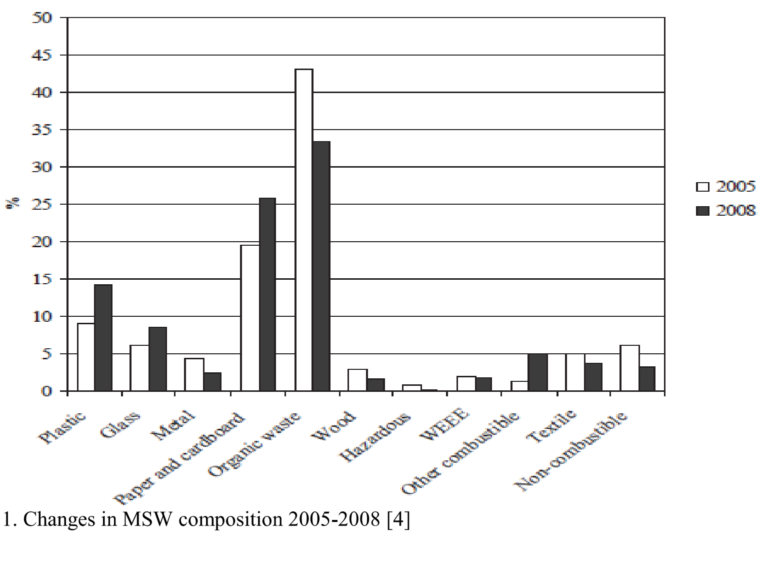

Fig 1. Changes in MSW composition 2005-2008 [4]

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.

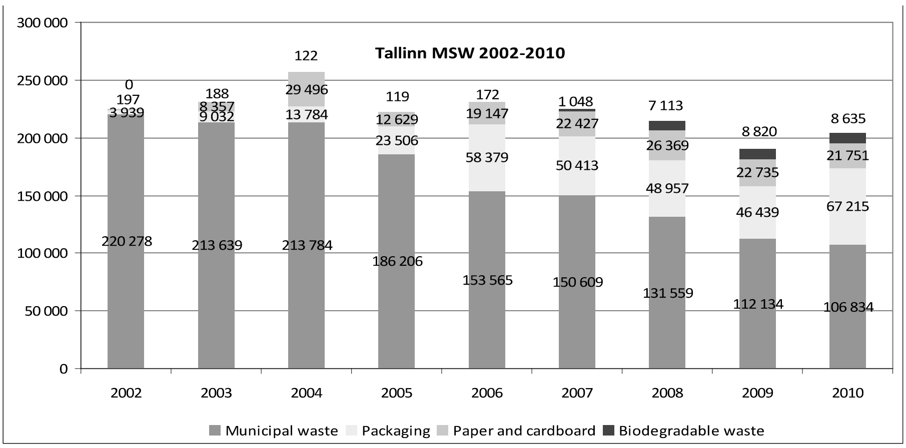

Fig 2. Waste generated in Tallinn 2005-2010, tons (Statistics Estonia 2011)

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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Jana Kivimägi planned and developed the organised waste collection scheme in Tallinn City Government while working at Tallinn Environmental Department Waste Management Division as a chief specialist in 2003-2006, and the head of the division 2007-2010. In 2011-2012 she was an expert in the "Development of waste management cooperation in Harju County Municipalities" project. Therefore, all the arguments and conclusions that are not from other authors indicated in the references are based on the practical work experience of the author.

PAPER III

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THE REORGANISATION OF WASTE MANAGEMENT IN HARJU COUNTY MUNICIPALITIES THROUGH A WASTE MANAGEMENT COOPERATION AND COMPETENCE CENTRE. A SOCIO-ECONOMICAL FEASIBILITY STUDY

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Abstract

The current paper presents the socio-economical feasibility study on the reorganisation of waste management in Harju County through waste management cooperation centre. The objective of the research was to estimate the improvement of administrative efficiency, and economical cost-effectiveness resulting from reorganisation of waste management administration. In the analysis two different scenarios were assessed in comparison of the current situation (basic scenario) from the aspects of economical and administrative cost-effectiveness. The waste management situation and cash flow, including waste collection services, source sorting options, waste holders and municipal budgets of waste management administration were mapped. Also a risk assessment of the qualitative indicators was compiled. The main problems of the basic scenario stand in the administrative inefficiency and financial shortage of waste management. The analysed project scenarios enable to improve both administrative efficiency, and solve the funding issue through the direct implementation of polluter pays principle. The municipalities delegate particular waste management duties to the cooperation organisation which reduces the administrative load in municipalities. The public collection network for sorted waste is taken over by the cooperation organisation as well as public awareness raising activities. The financing model of the public waste management bases on the budgets of the municipalities. In case of the full-scale scenario some of the public waste management expenses are integrated into the waste collection fee as administrative expenses. The main results of the research showed that the municipalities can win both financially and in administrative efficiency from the reorganisation of waste management through the cooperation centre.

Keywords: Integrated solid waste management, municipal waste collection, public procurement, recycling and recovery, socio-economical feasibility

1 Introduction

EU Directive 2008/98/EC (waste directive) insists that development of waste legislation and policy is a fully transparent process, and requires that the member states take measures to ensure waste undergoes recovery operations, and to develop the necessary collection system for the mixed municipal waste generated in private households [EC, 2008a, Articles 4, 10, 11, 13, 16]. Since 2005, the organised waste collection scheme (OWCS) has been applied step by step in the Estonian local authorities. The definition for OWCS given in the Estonian 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 [EP, 2004, § 66-1].

In the current paper, the waste management (WM) situation in Harju County municipalities is analysed from the aspects of socio-economical feasibility and environmental sustainability, and alternative WM scenarios for the municipalities are drawn. The principle of the advanced OWCS is introduced in details. In the local authorities of Harju County, which altogether host 153,492 inhabitants, the main stumbling block is administrative inefficiency. The reorganisation of the waste management through a waste management center (WMC) would enable a reasonable and effective sharing of the particular waste management tasks so that one specialist handles e.g. issues related to source sorting or public waste stations and collection points network, the other deals with public procurements, another specialist works out the local legislative regulation and waste management plans, organises public relations, advising and awareness raising actions, separate officers execute supervisory or manage waste holders register etc.

The waste management situation of Harju County municipalities was mapped and the socio-economical cost-benefit analysis was compiled within a project “Development of waste management cooperation in Harju County Municipalities”, granted by the European Structural Assistance to Estonia. The aim of the project was to rise the administrative efficiency in the Harju County municipalities, to improve the cooperation in waste management sector, and to provide high-quality municipal waste collection services according to the principles of the sustainable development in the county [HOL, 2012].

In response to the results of the project and the analysis, the non-profit waste management cooperation organisation Communal Services Center of Harju County (HUK, Harjumaa Uhisteenuste Keskus), was established in June 2012 by nine Harju County municipalities comprising 58,783 inhabitants. To date, HUK is gradually taking more responsibility and waste management tasks from its members. The ultimate objective of the organisation according to the full scale scenario is to become the waste management administrative body, cooperation and competence centre, and municipal waste collection customer service for all the 23 municipalities of the county and their inhabitants, involving range of activities such as executing the advanced OWCS, management of public waste stations and collection points for recyclables and domestic hazardous waste, and public awareness raising campaigns.

Although involvement of private sector in waste management can help to increase efficiency and effectiveness, it requires an organized public institution to monitor their activities. Sustainable solid waste management will require the involvement of all stakeholders concerned with generation of waste materials, collection and disposal as well as monitoring of activities regarding waste management (e.g. government, private sector and local residents) [Ezebilo and Animasaun, 2011, 682].

2 Materials and methods

2.1 Legislative Background of the OWCS

The main principles of OWCS are outlined in the Waste Act, as follows:

- municipality organises the collection and transportation of the municipal solid waste, including source sorted waste and sorting residues on its administrative territory;
- municipality may delegate the administrative tasks related to execution of the OWCS to other municipality or a non-profit organisation which member the municipality is;
- OWCS may be organised so that the only client and payer of the waste collection fee to the waste collection enterprise is the municipality or a non-profit organisation authorised by the municipality or municipalities;
- territory of a local authority is divided into waste collection districts involving approximately, in general case no more than 30,000 inhabitants;
- a service concession public procurement is held by the municipality or authorised non-profit organisation to choose the waste company, and the licence to provide the municipal waste collection service in the district is granted for up to five years;

- waste holders, both civilians and enterprises, are bound to join the waste collection service at their place of residence or activity, which means that the incorporation to the waste collection system is property-based;
- waste collection fee must be sufficient to cover the investment, operational, closing-down and post-closedown costs of a waste treatment facility as well as the cost of administration, collection and transportation of municipal waste, in consideration of the waste class, amounts and properties, collection interval, and other circumstances which have impact on the costs of the waste treatment;
- municipality organises recycling, recovery and disposal of the waste involved to the OWCS [EP, 2004, § 66-70].

2.2 Waste Management in Harju County

The waste management situation in Harju municipalities was mapped by questionnaires addressed directly to the WM specialists working at the municipalities (quantitative data) and oral interviews with officers from five selected municipalities (qualitative data). 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.

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 [KOP, 2013]. Five of the municipalities represent towns, while the remainder are parishes with village centres and mainly dispersed settlement. Regarding the project, the important socio-economical indicators are those of population and distribution of the waste collection districts. In general, the number of population and population density are relatively low in the Harju County municipalities.

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, except Kernu and Nissi parishes, which formed a joint district, and Koue parish, which is a member of the Central Estonian WMC and belongs to a bigger waste collection district of that WMC. In the Figure 1, the projected enlarged waste collection districts are drawn, which would optimise the waste collection routes.

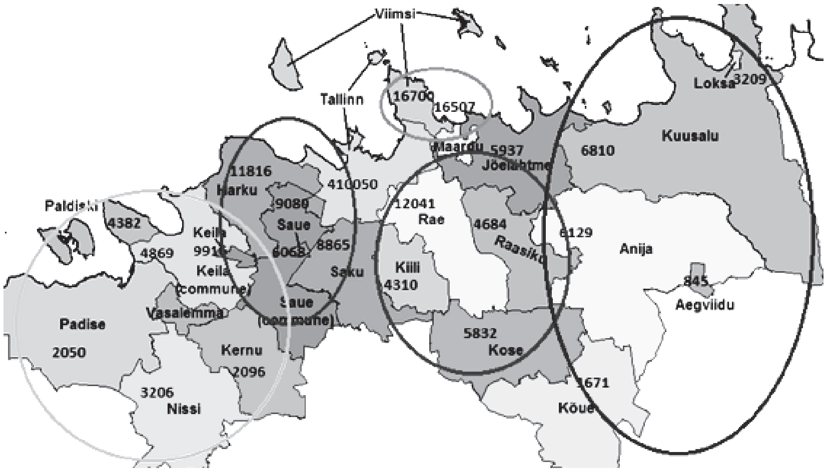

Figure 1. Map of Harju County, numbers of inhabitants and projected waste collection distícts [KOP, 2013 and Kivimagi, 2011]

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 mandatorily incorporated to the OWCS, meaning they have to organise their waste collection and treatment by their own [Kivimagi, 2011].

2.3 The Socio-Economical Cost-Benefit Analysis

The cost-benefit analysis was carried out by the Estonian Center 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 WM data of the Harju County municipalities and 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 WMC and implementation of the advanced OWCS [Jarve, 2012, 4]. The European Commission's methodology for the cost-benefit analysis of investment projects was used for the analysis [EC, 2008b].

The geographical measure of the analysis involves the Harju County municipalities, except Tallinn. The reason for the exclusion of Tallinn is that the main impacts which are in the focus of the analysis (the financial and administrative benefits and savings resulting from the transition from smaller public procurements separately executed in each local authority to bigger joint public procurements) are insignificant and marginal in Tallinn, which comprises nearly three times more inhabitants (419,830 inhabitants versus 152,728) [Statistics Tallinn, 2013] and three times more mixed municipal waste (94,127 tons versus 31,570 tons, 2012) [EEIC, 2012] on 26 times smaller territory (158 km^2 versus 4,163 km^2) [KOP, 2013] than rest of the Harju County municipalities together.

2.3.1 Financial Analysis

The technical data, investment costs, administrative costs and data regarding possible decrease of particular costs are gathered from sources like waste collection price lists in different municipalities, interviews and questionnaires with the waste management officers of the Harju County municipalities and other public sources like Statistics Estonia and Register of Population). The prognosis of the prices bases on the guidance materials of the Ministry of Finance [EMF, 2009].

The aim of the financial analysis is evaluate the cost-benefit of the project from the organisation's point of view. The cash flow is analysed and in comparison of two scenarios the cost-effectiveness of investments is analysed. Two input tables are compiled, the table of costs and benefits and the table of investments. Based on those tables the net present value (NPV) of the cash flows generated by the investments is analysed and cost-effectiveness of the investments are evaluated. The net present value (NPV) of cash flow is found according to the following equation:

$$FNPV(S) = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \cdots + \frac{S_n}{(1+i)^n}$$

, where

FNPV – financial net present value;
S – net cash flow;
n – number of periods (in the current project 30);
i – discount rate;
a – discount coefficient.

After that the financial sources are described and the financial sustainability of the project is evaluated. The analysis is focused only on those benefits and costs which are directly linked to the project, e.g. only those costs in the municipality's budget are taken into account which the realisation of the project may considerably change. Another important principle is that the analysis is always carried out in comparison of two scenarios (investment scenario minus base scenario). The advantage of this approach is that if the investments enable to reduce the expenses in the base scenario, the benefits arising from the investments are clearly detected in the comparison of two scenarios [EC, 2008b].

2.3.2 Risk and sensibility assessment

In the current research the risk and sensibility assessment was carried out in two stages:

1) Mapping of the risks using the standard approach of the risk register where two different rates are assigned on the risks: a) the rate to characterise the impact accompanying the realisation of the risk on the results of the project, where “5” means very big impact, “4” big impact, “3” moderate, “2” small, and “1” very small impact; and b) the rate to characterise the probability of the realisation of the risk, where “5” means almost sure realisation, “4” rather probable, “3” possible, “2” not really probable, and “1” improbable realisation of the risk. Based on the mentioned rates the risk score is calculated by multiplying the rates. According to the value of the multiplication the events will be divided into four groups: a) events with very high risk (score 15-25); b) events with average risk (8-12); c) events with some risk (4-6); d) events with negligible risk (1-3). The events of very high and average risk score should be provided with countermeasures, the events of some risk the factors reflecting the development of the risk should be followed up.

2) For the risk and sensibility assessment the Monte Carlo simulation is carried out. It is presumed that all the critical variables may vary occasionally within the limits of the probability function, and based on those occasional values the expanded FNPS is calculated. After that the new occasional values are assigned to the variables and the expanded FNPV is calculated again, and the process is repeated 500 times. As the result of the calculation the probability distribution and expected mean value of the expanded NPV are detected. The mean value may be bigger or smaller than the value calculated in the socio-economical analysis depending on whether the accompanying risks are higher or lower [Jarve, 2012, 73].

2.3.3 The Project Scenarios

Basic Scenario (S0) – the waste management is organised as it was before. The Harju County municipalities organise waste management independently, there is no overboundary cooperation. One or more officers in each municipality execute the waste management tasks, such as implementing the OWCS, occasionally/periodically upgrading legislative documents like waste management action plan and waste regulation, dealing with public maintenance and supervisory, managing public collection points for source sorted waste, running awareness raising activities and keeping the waste holds register. The waste management costs in the municipality’s budget (running public waste stations and collection points, domestic hazardous waste collection and treatment, awareness raising activities, public maintenance and trash bins, supervisory and administration of waste holders register, consultancy and legal advisement) are covered from income tax, environmental tax, financial support is requested from different programmes and funds. Waste holders pay the waste collection fee only for the municipal waste produced at their property.

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/joint waste collection districts (figure 1) by the WMC which reduces the administrative load (less public procurements are organised) and costs (the same amount of administrative tasks are executed with less number of officers) 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. The financial benefits to the inhabitants as well are expected from implementation of this scenario since in addition to the improvement of cost-effectiveness in the local authorities, the joint waste collection districts increase the volume of the service which may increase competition on the public procurement and result in lower waste collection and treatment fees.

Full-scale Project Scenario (S2) – in addition to S1 scenario, the advanced OWCS is applied which redirects cash flow from "waste holder → waste company" to "waste holder → WMC → waste collection company and waste treatment company". The WMC takes over some administrative functions from the waste company (customer service, accountancy). Part of the public WM expenses (awareness activities, domestic hazardous waste collection, waste holders register) is integrated into the waste collection fee as administrative expenses. This new financial source frees the budgets of local authorities from the mentioned WM expenses. The financial benefits to the inhabitants are smaller than in case of the limited project scenario because the "polluter pays" principle is applied on the larger range and the start-up investments of the WMC are also reflected in the waste collection fees [Kivimagi, 2011 and Jarve, 2012, 5].

2.3.4 Questionnaires and interviews carried out in the Harju County municipalities

The questionnaires involved detailed information about WM situation, legislation and costs in the municipalities budget, collection options for source sorted waste (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 waste collection contracts and contractors), waste holders register and the waste collection fees. Fully and relevantly filled questionnaires were returned from 19 municipalities [Kivimagi, 2011].

The interviews with WM officers from 5 selected municipalities (Harku, Joelahtme, Kernu and Saku parishes, and Saue town) covered the topics such as estimation of working time on particular waste management tasks, main problems and challenges in implementation of OWCS and other WM tasks. The average number of inhabitants of the selected municipalities were approximately 7,600 which is a bit higher than average in Harju County (excluding Tallinn), but both the municipalities with population under 3,000 inhabitants and above 10,000 inhabitants were represented [Jarve, 2012, 25].

Tabel 1. The WM tasks and time spent on execution of those tasks in Harju County municipalities [Jarve, 2012, 26]

Waste management tasks	Days a year	Proportion in WM tasks
Updgrading and composing WM action plan, waste regulation and other legislative documents, tracking their performance, development of WM infrastructure	12	6,5%
Keeping waste holders register	41	22,2%
Management of public ollection points network and waste stations, collection of domestic hazardous waste and source sorted recyclables	24	13,0%
Implementation of the OWCS, public procurements	2	1,1%
Supervisory on OWC contractor, communication and issues with the contractor	36	19,4%
Supervisory on waste holders unincorporated to the OWCS, dealing with exemptions and applications for exemptions	36	19,4%
Awareness raising activities, advising, councelling	34	18,4%
TOTAL	185	100%
Number of working days a year	255	73%

3. Results and discussion

3.1 The main waste management problems in Harju County municipalities

3.1.1 Administrative inefficiency and lack of competence

The numbers of inhabitants in the municipalities range from 764 to 17,671 [KOP, 2013], 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. [Kivimagi, 2011]. As it is revealed from interviews and presented in the table 1, in an average municipality 0,73 full-time work load is needed for waste management tasks [Jarve, 2012, 25]. This makes 16,8 full-time work loads

(23 · 0.73 = 16.79) per whole Harju County and 0.11 work loads per 1,000 inhabitants.

Based on the work experience at the Environmental Department of Tallinn City Government, the author confirms that the implementation of the OWCS (organising public procurements and managing the concession contracts, keeping waste holders register, advising waste holders, supervisory on waste holders) in a municipality comprising nearly 420,000 inhabitants needs a full-time work load of six chief officers, and 0.5 part-time work load (management, coordination) of the head of the waste division in the Environmental Department and one officer (dealing with the exemptions, advising and supervisory) in each city district (8), estimatedly total 14.3 full-time work (6 + 0.5 · (1 + 8) = 10.5) loads which makes 0.025 workloads per 1,000 inhabitants. Thus the administrative efficiency per capita is 4.4 times lower in Harju County compared to Tallinn City.

In addition, the lack of competence is revealed when analysing the WM legislative documents of the Harju County municipalities. In many cases the waste management action plans and waste regulations were expired and not in accordance with the state legislation. 15 municipalities out of 23 had waste regulations updated earlier than 2009 when some important changes in the National Waste Act came into force. The lack of competence appeared also in the OWC public procurement documents resulting in oppositions and suing of the OWC procurements by the waste companies in 10 municipalities. In 9 cases exterior competence like legal advisement or public procurement consultancy was bought in [Kivimagi, 2011].

An organization can have an organisational structure designed for flexibility without having to make compromises on the level of (organisational) efficiency. Nevertheless, while improved organisational efficiency implies improved administrative efficiency, through reducing the administrative overhead, flexibility will at best have a neutral influence on administrative efficiency [Evans and Davis, 2005].

According to Fox and Gurley (2006), the declared main goals of municipal concentrations are falling service delivery costs, more even or equitable provision of services and better planning across a metropolitan area. For the Nordic countries Steineke (2010) concludes: “In all Nordic countries, a central argument in promoting municipal mergers is that public welfare services are more efficiently produced in larger municipalities.“ [Bonisch et al, 2011, 5].

The reorganisation of WM through a cooperation and competence would mitigate and/or eliminate both the administrative inefficiency and lack of competence regardless which project scenario would be implemented. The WMC can compile a regional waste management action plan and appropriate drafts for waste regulation and public procurement documents.

3.1.2 Lack of waste, inhabitants and cooperation

The number of inhabitants and sizes of the territories vary on a large scale as well as the indicators of the waste generation per capita and per square kilometre. Although there are some municipalities with higher population density (e.g. Saue town 1,358 inh/km^2), the median of the population density in Harju County municipalities is only 51 inh/km^2 (average 210 inh/km^2), the size of an average collection district is 6,977 inhabitants and 190 km^2, and annual MMW generation 1,432 tons (2012). Considering only the number of inhabitants, all the municipalities form remarkably smaller waste collection districts than allowed by the Waste Act (30,000 inh, see chapter 2.1). Since the OWC public procurements have been held individually and in different time the waste companies (5 different enterprises sharing the market in Harju County) also differ in the neighbouring municipalities in many cases, meaning the waste collection routes cannot be optimised over-boundarily [Kivimagi, 2011].

As mentioned in chapter 2.2, most of the Harju County municipalities do not cooperate and have organised WM independently. In the table 2 the projected enlarged waste collection districts are presented with the timetable of transition. The districts are formed from neighbouring municipalities comprising roughly number of inhabitants according to the regulation of the Waste Act. The projected transition period depends on the validity of the current OWC contracts.

Table 2. Projected waste collection districts, timing of transition and implementation of the OWCS [Kivimagi, 2011]

Waste collection district	Inhabi-tants	Territory (km^2)	MMW (t/y)	Period of transition
Keila parish, Keila town, Kernu, Nissi, Padise, Paldiski town, Vasalemma (I)	28,417	1,095	5,528	2013-1/8/2016
Harku, Saku, Saue parish, Saue town (II)	38,140	530	8,886	2013-1/1/2016
Maardu town, Viimsi (III)	34,029	96	8,211	immediately
Joelahtme, Kiili, Raasiku, Rae (IV)	29,302	677	4,969	2013-1/1/2014
Aegviidu, Anija, Kose, Kuusalu, Koue, Loksa town (V)	23,604	1,777	3,901	2013-1/6/2014

The new OWC public procurements can be arranged so that municipalities join the new OWCS when the previous contract ends. The enlarged waste collection districts can be applied in case of both scenario S1 and S2. The main benefits arising from the enlarged waste collection districts are: 1) the optimisation of the waste collection logistics and routes, increase of the waste amounts and number of waste holders in a district which may tighten the competition and reduce the waste collection fees at the procurements, 2) and decrease of the number of public procurements (5 OWC procurements instead of 21 in a five year period) which increases the administrative efficiency.

3.1.3 Limits of the WM budget in the local authorities

The waste management budget of a local authority is covered by two main sources: the landfilling tax from the municipal waste originating from the municipality and the income tax of the local inhabitants. The budget includes the municipality's expenses on the domestic hazardous waste collection, management of public waste station or collection points for recyclables and other source sorted waste, and awareness raising activities. The mentioned tasks are essential and compulsory administrative activities which a local authority in Estonia have to perform according to the Waste Act.

In Macedonia, in two regions with comparable characteristics (area, population, population density, ratio of urban/rural areas, waste generation) a study on issuing concession for regional integrated solid waste management was carried out. Waste management in Macedonia is not satisfactory due to the fact that the public sector has no financial capacity to invest in equipment modernization, has not built any landfills that would make sure that environmental impacts are minimized, and the price of the service has not been formed in a manner that would create an enabling environment for the *Polluter Pays Principle*. At present, it is the public utility companies that provide the solid waste management service in the majority of municipalities. This situation prevents competition, as a result of what the service level is not in line with the requirements of the European Acquis, nor are the principles underlying the Waste Management Law observed, which law has been fully harmonized with the relevant EU Directives. In addition to the unsatisfactory service level, the current costs for waste management are not covered because of the relatively low price of the service and the low rate of fee collection [MEPP, 2009].

In Harju County, most of the municipalities the awareness raising activities stand in the passive information about the WM regulation and options on the municipality's website, the possibility to call to the local officer on one's own initiative, and maybe a short news or an article in a local newspaper few times a year. Only six municipalities out of 23 spent some extra money on awareness raising campaigns in 2010 [Kivimagi, 2011]. The lack of advising and awareness raising activities results in waste holder's ignorance and disregard which appears in littered public areas and collection points.

The coefficient associated with awareness of solid waste disposal laws has a positive and statistically significant effect on the respondents' perceptions of solid waste management services. This reveals that respondents who were aware about waste disposal laws were more likely to be satisfied with solid waste management. If a respondent is informed about laws regarding solid waste disposal, the probability of being satisfied with solid waste management increases by 0.099. People who are informed about laws are often more learned and should know more about rights regarding the environment [Ezebilo and Animasaun, 2011, 684].

The reorganisation of the WM through the WMC synchronises the public collection options for source sorted waste and improves the waste awareness regionally by taking those administrative tasks over from the municipalities regardless which project scenario would be implemented.

3.2 The financial feasibility and qualitative benefits of the Harju County WMC

3.2.1 The Financial Net Present Value

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 FNPV). 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.

Relying on the main results of the socio-economical cost-benefit analysis for the Waste Management Centre of Harju County Municipalities, 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 (table 3), meaning the municipalities can financially win from the reorganisation of waste management through the cooperation centre.

Table 3. The Investments Profitability Index [Jarve, 2012, 6]

Scenarios	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

In case of scenario S1, the benefit 1.2 million euros comes from the labour saving, meaning the WMC is capable of executing same amount of WM tasks with less number of employees – the gain stands in improvement of efficiency. This number can be interpreted so that if the Harju County municipalities decide for implementation of the scenario S1, then in addition to that, they can development their waste management and implement additional WM activities in the range of expenses which NPV don't exceed

1.2 million euros, and the total WM expenses of a municipality still stay lower than those are in case of scenario S0, meaning present situation.

In case of scenario S2 the benefit for local authorities is remarkably bigger (4.7 million euros) because some for the WM activities presently financed from the municipalities budget will be transferred on the wallets of inhabitants/waste holders, and same time the income of the municipality doesn't decrease. In this case the municipality wins in all the expenses which accompany the WM tasks the WMC would take over.

Observing the financial profitability of the project from the waste holder's point of view (the expanded FNPV), then the outcome is different because the scenario S2 brings along increased costs (investments, loan interest, V.A.T) while the scenario S1 delivers to the inhabitants the majority of the benefits arising from the implementation of the project with less expenses.

3.2.2 Qualitative risk assessment

In the table 4 some selected and most important risks are presented which realisation may affect the results of the project in a negative way. The risks are provided with the countermeasures which would mitigate or eliminate the impact and probability of the realisation of the risks.

Table 4. Selected risks, their impact, realisation probability and countermeasures [Jarve, 2012, 64-66]

Risk	Impact	Probability	Score	Explanation and countermeasure
Some municipalities are not willing to cooperate – the project may become more expensive for the incorporating members, or the expected market share cannot be gained because the procurements cannot reasonably conjoined.	5	4	20	It is an important risk. The only reasonable countermeasure is communication between and within the municipalities and explaining the benefits of cooperation. Both the project team and HOL must contribute to this.
There will be more opposition and suing of the OWC procurements which will cause the delay of the launching the WMC and the advanced OWCS.	4	5	20	The impact is big and probability very high, but the problems can be anticipated and mitigated by highly professional and juridically reliable public procurement documents.
Separation of waste collection company and customer service (scenario S2) brings along the communication issues and the service quality may drop, especially in the phase of launching the project. The clients are not satisfied and the qualitative benefits will be not realised.	4	4	16	Such developments have a big impact and without countermeasures the realisation probability would be also high. To avoid it a quality management system should be implemented where all the procedures are described in details.
Lots of overdues and delayed payments or bills unpaid by waste holders, which increases the need of circulating capital and decreases the profitability of the project.	4	3	12	The impact would be big and probability moderate. The countermeasure is careful planning of the finances, also strict supervisory and prosecution in cooperation with municipalities.

3.2.3 The qualitative benefits arising from the project

Both of the project scenarios are financially and socio-economically beneficial compared to the base scenario S0, yet there are some important qualitative impacts which emerge especially in case of scenario 2:

1) All the WM services are provided by the WMC, one and stable contractor for a long time. WMC provides the waste collection and treatment service, customer service and call centre, advising, counselling and other WM information, including source sorting, OWC service details, billing, solvation of the current problems and complaints on the waste collection etc. Waste holder has a single contractor for all the WM services regardless the waste collection enterprise may change in every five years due to the public procurements. For all the WM services there are unified and systemised website, message and graphics.

2) The quality of the WM services improves. There are unified waste collection service quality, conditions and fees for all the WM services in all the waste collection districts. The waste collection service will be equally available for a fair price all over the county both in village centres and periphery, independent on the waste collecting company or waste collection district. The quality, conditions and fees of the public collection network for source sorted waste and recyclables will be unified. The WMC is responsible for the quality of the WM services.

3) The cash flow is transferred through the WMC. 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. Savings in the administrative costs arise from the consolidation of the supporting services and economy of scale. WM service fees are transparent, all the components of the waste collection and treatment costs are separated, services are procured by WMC. Some of the expenses of the public collection network are integrated to the waste collection fee, thus the waste holders are motivated to sort waste and use the public waste stations or collection points.

4) Public network of waste stations and collection points is unified regionally. The network of public containers, collection points and waste stations is optimised geographically. Conditions and information about the source sorted waste and its acceptance are unified all over the county.

5) Supervisory becomes more efficient. The WMC can provide the municipality with immediate input for supervisory and procedural act. The debtors will be not only left out from the waste collection service but also prosecuted.

If the local authorities consider the qualitative impacts arising from the project sufficiently important, then it would be reasonable to implement the scenario S2, if not then the results of the financial analysis support the implementation of the scenario S1.

4 Summary

The benefits, regardless of which project scenario would be implemented, arise mainly from three circumstances:

- the improvement of the administrative efficiency: the WMC is capable of doing the work of the municipalities with less number of employees;
- the optimisation of waste collection logistics and transportation – instead of 23 municipalities and waste collection districts, the enlarged over-boundary waste collection districts are formed between several municipalities;
- 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.

From the aspect of local authority both scenarios are worth of implementation – the FNPV is bigger than zero in both cases, meaning the municipalities can financially benefit from the reorganisation of WM either according to the scenario S1 or S2. Considering the financial indicators only and presuming that to a local authority financial benefit for the inhabitants is the priority, then the scenario S1 should be implemented. However, the scenario S2 involves several qualitative advantages, which also should be considered. For a municipality it is definitely important, that the scenario S2 enables to launch a whole new financial source (waste collection fee where to some of the WM cost are integrated) for the WM tasks thus freeing the budget for those expenses. In addition, there are several qualitative advantages which unfortunately were not possible to evaluate quantitatively but which occur better in case of scenario S2.

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.

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.

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PAPER IV

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Section: Environmental protection

Utilisation options for biodegradable kitchen waste in Estonia. SWOT analysis

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Abstract

The most critical issue in municipal waste management in Estonia is the biodegradable fraction because the source sorting and central collection and treatment of that fraction is neither economically nor environmentally cost effective. Over the last three years, scientists from Tallinn University of Technology (TUT) collected data about the biodegradable waste produced in Estonia during 2002–2012. The waste volumes, qualities, and energy potential were estimated. Biodegradable waste, such as manure, sludge and biomass from unused lands, is the best resource for renewable energy production in the anaerobic digestion process in Estonia. The current paper focused on the waste from trade companies, garden waste and kitchen waste because the quantity of this type of waste has gradually increased in recent years. The SWOT analysis shows that the composting method for the utilisation of this type of waste is a better solution. Also, the benefits and disadvantages of home composting and central collection and treatment of bio-waste are analysed.

Keywords: anaerobic digestion; biodegradable waste; composting; kitchen waste; SWOT analysis.

Nomenclature

MSW	Municipal Solid Waste
SEIT	Stockholm Environment Institute Tallinn Research Center
TUT	Tallinn University of Technology
WWTP	Waste Water Treatment Plant

1. Introduction

The Estonian Waste Act in accordance with the Directive 2008/98/EC of the European Parliament [1] and of the Council of 19 November 2008 on waste requires that the percentage of biodegradable waste in the waste disposed to the landfills does not exceed 35% since July 2013 and 20% from July 2020. The Waste Act [2] also prohibits disposal of untreated waste in landfills. However, some recent researches show that the bio-waste content in the municipal waste amounts to 50% or even more [3]. Therefore, the most critical issue in municipal waste management in Estonia is the biodegradable fraction because the source sorting, and central collection and treatment of that fraction is neither economically nor environmentally cost effective. Biodegradable waste, such as manure, sludge and biomass from unused lands, is the best resource for renewable energy production in the anaerobic digestion process in Estonia [4]. Their economically usable energy potential was estimated to be around 112 mln. m^3 per year [5]. Other biodegradable waste, such as waste from trade companies, waste from gardens and parks, as well as kitchen waste may decompose under anaerobic and aerobic conditions. The future for biodegradable waste using as a resource for renewable energy depends not only on the availability of the equipment, but also on economic- and political factors. The focus of this paper is on organic waste from trade companies, garden waste and kitchen waste, because the quantity of this type of waste has gradually increased in recent years. Kitchen waste and waste from trade is mostly fibrous- and well structured. These properties are optimal for composting, but the waste can also be used for biogas production in a dry digestion process [6]. The main composting type for source separated organics in

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Finland, Germany, UK, Ireland and France is composting in open windrows [7]. The objective of the research was to estimate the utilisation options for kitchen waste, waste from trade companies, and terrace and gardening waste in Estonia.

2. Materials and Methods

Over the last three years, scientists from TUT collected data about the biodegradable waste produced in Estonia during 2002–2012 in all 15 counties. The data about the amount of waste generated were received from the Estonian Environment Information Centre, from official statistics and from TUT research projects. The data collected by the scientists of TUT involved all types of biodegradable waste, such as total municipal waste, terrace and gardening wastes (including cemetery waste); biodegradable waste from 98 food industry companies, sewage sludge from 145 wastewater treatment plants, waste from 264 trade companies, manure from 292 farms and energy crops from all 15 counties of Estonia. The current article focuses on the waste from trade companies, garden waste and kitchen waste in Tallinn and Harju County, because the quantities of this type of waste have gradually increased in recent years. The method of statistical analysis using Mathcad 2001 Professional software was applied for the received data evaluation, and SWOT analysis was carried out for the comparison of different methods of bio-waste utilisation.

3. Results and discussion

Municipal solid waste (MSW) is typically composed of a biodegradable organic fraction, such as kitchen scraps, food residue, food processing waste, and grass cuttings that are suitable feedstock for biogas production plants. Also, MSW consists of a combustible fraction, like wood, paper and paperboard, textile, which are suitable for incineration-based energy generation plants. MSW also consists of non-degradable fractions such as metal, glass, sand and stones which need to be removed. Table 1 shows the composition of mixed municipal waste in Estonia [8].

Table 1. Mixed municipal waste (landfilled) composition (%) in Estonia

Waste components	2008
paper and cartoon	18
kitchen waste	30
plastics	19
glass	8,1
waste from gardens	5
combustible material	6,3
non combustible	4,3
textile	4,4
metal	2,5
electronic waste	0,6
wood	0,4
other bio waste	1,4
Total	100

The biggest parts of waste components consisted of kitchen waste, followed by paper and cartoon. The quantity of other components was smaller. According to research on the composition of mixed municipal waste in Estonia, which was carried out in 2012/2013 by SEI Tallinn Research Center, the average mixed municipal waste contains 31.8% of bio waste (kitchen waste, garden waste, other bio waste) and 13.5% of paper waste, which can be included in the biodegradable fraction of municipal waste [9]. The World Bank study summarised biogenic waste as a mean of 64% for low-income countries, 59% for middle-income countries, and 28% for high-income countries [10].

During the period from 2002 to 2010, the average quantity of municipal solid waste in Estonia was around 507,000 tons/year. The maximum quantity of municipal solid waste was produced in 2007. Since 2008, the quantity of generated waste has been constantly decreasing, which is connected to the slowdown of economic growth in the country. Approximately 381,000tons of municipal solid waste was produced in 2012, which was smaller by up to 41% compared to 2007. The quantity of municipal solid wastes varies from county to county and from town to town, but and the largest quantity of MSW during 2002–2010 was generated in Tallinn.

Biodegradable waste generation of trade companies is increasing from year on year with an increasing number of stores. In 2010, the quantity of this type of waste was approximately 3 times more (14,300 tons) than in 2004 (5,340 tons). The average quantity of biodegradable waste generation in Estonia from grocery stores during 2004–2010 was 9,103 thousand tons/year. The largest amount of biodegradable waste from trade companies was generated in Harju County (2,862 tons/year) because there is a large population, more shops and the largest town in Estonia–Tallinn, is located there.

In Estonia, only 2,189 tons of terrace and gardening waste were generated in 2002, but in 2009 the growth of waste was significant (22,094 tons). This increase in waste was explained by the increased waste disposal in Tallinn cemetery in 2009 and 2010. The largest amounts of terrace–and gardening waste generation during 2002–2010 were in Harju County. The largest waste producer was Tallinn cemetery.

The collection and analysis of kitchen waste (Table 2) was only conducted in Tallinn and Harju County, as they are the biggest source for this waste pollution in Estonia. Up to 2004 all kitchen waste (100%) was sent to landfill, but since 2006 waste reusing has been implemented.

Table 2. Kitchen waste income and reuse during the years 2004-2012 [11]

Years	Income, incl. generated (tons/year)	Reuse	% of reusing	% of landfilled
2004	0,087	0		100
2005	0,864	0		
2006	0,129	0,134	100	2
2007	1,592	1,599	100	
2008	8,146	8,144	100	0
2009	9,805	9,491	97	0
2010	10,653	10,057	94	
2011	10,957	8,556	78	2

Tallinn is the first town in Estonia were municipal bio-waste (kitchen waste) has been collected separately. Kitchen waste includes organics matter, such as fresh fruit and vegetables, prepared foods, cooked and uncooked meats and fish, and other foods: cheese and eggs, bread, coffee grinds, tea bags, etc. wilted flowers, tissue paper. The properties of kitchen waste are optimal for composting.

Many local authorities, which comprise settlements and areas of high population density, have imposed the separate collection of bio-waste on houses with more than 10 apartments. In houses with fewer than 10 apartments, the source sorting of bio-waste and composting on site is still recommended but a separate container for bio-waste is not compulsory. The majority of separately collected bio-waste in Estonia is produced in Tallinn. In 2012, the total amount of separately collected organic kitchen waste (code 20 01 08 in the List of Waste 2000/532/EC [12]) in Estonia was 12,838 tons, of which 10,375 originated in Tallinn and 1,027 in Harju County [13].

The separate collection of bio-waste was implemented in Tallinn with an organised waste collection system in 2007, and it was remarkably successful. The number of bio-waste containers in Tallinn has now 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 fewer than 10 apartments practice the home composting of bio-waste in their backyards [14]. The Estonian Ministry of the Environment has carried out a questionnaire [15] about the waste management situation amongst Estonian local authorities. According to the survey, most of the local composting facilities are either at the wastewater treatment facilities where sludge is processed with a marginal amount of gardening waste, or facile open windrow composting sites for gardening waste. Technologically equipped composting facilities where biodegradable kitchen waste can also be processed are only at the regional landfills or waste stations [15]. Therefore, in most of the municipalities the collection routes for separately collected bio-waste are long, which makes the transportation costs high and the economical feasibility of central collection of bio-waste questionable.

The quantity of generated biodegradable municipal waste in Estonia (ton per year) and Tallinn was presented in Table3. The Table 3 shows, that 37% of MSW of Estonia was generated in Tallinn, therefore, in this table the waste from trade companies, kitchen waste, terrace/ garden waste and food waste was only presented for Tallinn and Harju County.

Table 3. Quantity of municipal waste generated in Estonia, in Tallinn waste from Harju County

NN	Type of waste	Waste quantity (thousand tons per year)						
		2004	2005	2006	2007	2008	2009	2010
	Total MSW in Estonia	558	478	518	579	513	441	413
1	MSW of Tallinn City	210	186	180	197	178	172	154
2	Trade	1.403	1.379	1.180	1.040	3.231	6.073	5.727
3	Kitchen waste	0.087	0.864	0.129	1.592	8.146	9.805	10.653
4	Terrace and gardening	0.065	0.754	0.501	0.410	0.558	17.922	9.198
5	Food Industry	9.578	8.291	7.253	6.688	3.997	4.545	4.660

The value of industrial pollution constantly decreases and the share of industrial waste was an average of only 3.46% of MSW from Tallinn. The quantity of other waste, such as waste from trade, kitchen waste and waste from terrace and gardening has increased year on year.

3.1. Choice of a suitable method for waste from trade companies and kitchen waste

The anaerobic digestion process and composting are two ways to decrease of these waste types. The first option for possibilities of biodegradable waste utilisation is biogas production during the anaerobic digestion process. Today, only manure and sludge from WWTP with waste from the food industry is ready for use in biogas production in Estonia. The economically usable biogas quantity in Estonia such as waste from trade (0.1mln. m3/year) and terrace and gardening waste (0.3mln. m3/year) is very small [5]. The average quantity of kitchen waste is 5,279 tons per year and the theoretical potential of biogas production is only 0.5mln. m3/year. The economically usable biogas potential of this substrate in Estonia is only 10% [16] and the theoretical amount of biogas (0.05mln. m3/year) producing even less than for other waste types. The energy potential of this type of waste is very small and, therefore, the composting process may be better.

Composting is a process of controlled biological decomposition of biodegradable materials under managed conditions that are predominantly aerobic and that allow the development of thermophilic temperatures as a result of biologically produced heat, in order to achieve compost that is sanitary and stable [17]. Composting is an aerobic process where organic material is transformed through decomposition into a soil-like material called compost. It is a process that occurs naturally in the environment but, as a controlled process, composting can be an invaluable waste management tool, causing a volume and weight reduction in the raw materials and producing a potentially valuable end product. The product is rendered more stable and made suitable for application to gardens and productive land as a soil improver. When carried out under ideal conditions, the only outputs to the atmosphere from composting are carbon dioxide and water [18].

In basic equation form, the overall material balance for composting approximates to:

$$C_pH_qO_rN_s \cdot aH_2O + bO_2 \rightarrow C_tH_uO_vN_w \cdot dH_2O + dH_2O + eH_2O + CO_2 \quad (1)$$

The organic matter + oxygen → compost + water + carbon dioxide

The transformations that take place occur through a range of processes initially involving bacteria, fungi, moulds, protozoa, actinomycetes, and other saprophytic organisms feeding upon decaying organic matter, while in the later stages of decomposition, macroscopic organisms such as mites, millipedes, centipedes, beetles and earthworms further break down and enrich the composting materials [18].

Compost technology has three important functions, the first of which is “pre-processing”. Pre-processing consists of the preparation or processing of a raw waste such that it constitutes a suitable substrate for the compost process. The second function is the conduct of the compost process. The third function is the preparation of the compost product for safe and nuisance-free storage and/or the upgrading of the product so as to enhance its utility and marketability [19]. The technologies can roughly be divided into small-scale, domestic or local composting and large-scale, central or industrial composting. The large-scale composting usually involves technological measures for the better control of the whole process and quality of the compost, as well as to reduce the environmental impact like air emissions, leachate and pathogens. The distinctive features of different composting technologies are open or closed composting; with or without forced aeration; and different process techniques like windrow, container, box channel or tunnel composting.

Open-air windrow composting is the simplest technique. Generally, these plants work without forced aeration and waste gas collecting [20]. Windrow composting has been the common practice for large scale composting globally. This process is less costly than the other technologies but it is more difficult to control and it can generate undesirable emissions and odour’s [21].

In-vessel composting refers to a group of composting systems, which range from enclosed halls to tunnels and containers or bins. In-vessel systems attempt to create optimum conditions for the microorganisms, thereby giving improved control of the composting process and accelerating decomposition. As in all composting systems, the supply of air to all the material being composted is an in-vessel compost technology is promoted for managing food scraps in areas with limited space. This is a great solution as long as the compost unit's characteristics meet the needs of the institution managing the organic residual's key factor in determining the effectiveness of the process [17].

In-vessel compost technology is promoted for managing food scraps in areas with limited space. This is a great solution as long as the compost unit's characteristics meet the needs of the institution managing the organic residuals. There are a number of parameters to consider: amount of waste/week; amount of space available for primary and secondary processing; carbon material required and where it can be sourced and stored; batch or continuous feed; retention time; and space needed for curing. Odor control is one of the reasons in-vessel technology is employed. However, if the recipe or balance is not correct or if the compost system is not really designed to manage the intended feedstock, there will be odors and they will escape from any unit. Limitations of the chosen in-vessel unit must be identified [22].

Home composting is small-scale composting for domestic gardening and kitchen waste (without meat, bones or fatty foods). The main technologies applied for home composting are composting in an aerated (turned) pile or a covered/closed composting bin, mulching, soil incorporation and vermicomposting. Mulching is suitable for chopped yard waste (leaves, grass, branches), which is simply spread around the trees or on flower or vegetable beds. Soil incorporation is more suitable for kitchen scraps. Digging the kitchen waste into the ground also helps to avoid the odour problem.

Vermicomposting uses earthworms to turn organic waste into compost. The main negative environmental impacts accompanying composting process are air emissions (odour and greenhouse gases), pathogens and insects, and leachate. There are also some positive impacts such as the usage of compost as a fertiliser or soil amendment, avoiding disposal of biodegradable waste, reducing the amounts and environmental impact and costs of transportation and treatment of municipal solid waste, and contributing to the sustainable waste management model.

Two methods of organic matter decomposition were analysed and the results were presented in Table 4 and Table 5.

Table 4. SWOT analysis

SWOT	Aerobic degradation: industrial composting, home composting	Anaerobic degradation: biogas production, anaerobic digestion
STRENGTHS	Reduction of biodegradable fraction in disposed MMW, reduction of the environmental impact of landfills (landfill gas and leachate production), increases life-span of landfills	Reduction of biodegradable fraction in disposed MMW, reduction of the environmental impact of landfills (landfill gas and leachate production), increases life-span of landfills
	Low investments and operational costs compared to anaerobic digestion, facile technical requirements, home composting has a widespread applicability, no permits required	Can combine different sources of organic waste, such as: agricultural activities, slaughter houses, olive processing plants, waste water treatment plants etc
	Compost can be used to enhance soil nutrients for plant growth	Production of biogas which can be converted to energy
	Home composting reduces the waste transportation and treatment costs and environmental impacts of those	Fast process cycle
	National and EU legislation and necessary know-how exists	Controlled process, controlled gas, odor and wastewater emissions
WEAKNESSES	Limited range of input material, not suitable for sludge and other high moist containing materials	Limited range of input material, not effective/ optimal for gardening and other lower moist containing organic waste
	Slow process, but can be accelerated with agents and technological facilities (aeration, in-vessel, tunnel)	High investments and operational costs compared to aerobic composting, strict and technical requirements
	Problems related to the establishment of the facility (area selection, permits, social reactions)	Problems related to the establishment of the facility (area selection, permits, social reactions)
	Source sorting of bio waste requires separate collection infrastructure (bins)	Requires stabile and high-quality in-put material, thus not suitable for source sorted bio waste from households
	Uncontrolled greenhouse gases, VOCs and dust emissions unless additional technological facilities are used for gas collection	Need for post-treatment of digestate
	Attraction of rodents and insects, possible smell problems	
OPPORTUNITIES	Reduction of waste and greenhouse gas emissions, sustainable management of organic waste	Reduction of waste and greenhouse gas emissions, sustainable management of organic waste
	Suitable for bio waste generated in private households and detached houses areas, a closed loop model if compost as end product is used *in situ*	Harvest residues from agriculture, solid and liquid manure, biogenic urban waste, residues from the food industry, pulp and paper sludge, and sewage sludge are appropriate ingredients for anaerobic digestion
	Independent on the stabile input material flow, process can be adjusted according to the amounts of incoming bio waste	Biogas resulting by anaerobic digestion is a source of renewable energy because it replaces fossil energy
	Suitable for post-treatment of the digestate of anaerobic digestion	Under controlled conditions the digestate can be used as soil fertiliser
THREATS	Lack of awareness of citizens may result in poor quality of source sorted bio-waste and can lead to bad quality compost	Digestates differ greatly depending on input materials, process operation and retention time in reactor, thus may need a post treatment in aerobic composting
	Lack of demand for compost and accompanying products	Dependant on the stable and high-quality input material flow
	Lack of oxygen may turn the process anaerobic which contributes to the methane emissions and smell production	No legislation for the utilisation or compositional requirements of digestate
	Negative impact on the value and prices of surrounding real estate and properties	Negative impact on the value and prices of surrounding real estate and properties

Table 5. Comparison of two different methods for waste utilization

Comparison	Aerobic degradation: home composting, industrial composting	Anaerobic degradation: biogas production, anaerobic digestion
Essence	Aerobic degradation of organic waste to produce compost	Controlled decomposition of organic waste in the absence of oxygen
Technology	Aerated or static windrow, tunnel, in-vessel, vermicomposting	Reactor, methane tank
Investments	None or low or moderate	High
Operational costs	Low or moderate	High
Emissions	Uncontrolled, CO2, CH4, smell, leachate	Controlled, CH4, biogas
Preferred input material	Garden waste, kitchen waste, food residuals	Sewage sludge, manure, silage, wastes from the food and beverage industry
Outcome product	Compost, warmth	Biogas, energy, digestate

As tables 4 and 5 show, the aerobic degradation of kitchen waste and for waste from trade companies is the better variant for its utilisation.

4. Conclusion

The biodegradable fraction in mixed municipal waste in Estonia is considerable and it must be utilised, because its degradation is a major contributor to greenhouse gas emissions. This fraction of waste should not be mixed with another municipal waste.

The largest quantity of MSW during 2002–2010 was generated in Tallinn (37%). The separate collection of bio-waste was implemented in Tallinn with an organised waste collection system in 2007, and it was remarkably successful.

Today, only manure and sludge from WWTP with waste from the food industry is really to use for biogas production in Estonia. The quantity of waste from trade, kitchen waste and waste from terraces and gardening has increased year on year, but its energy potential is very small, therefore, the composting process is better.

The SWOT analysis has shown that the composting process is better solution for kitchen waste and waste from trade companies

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PAPER V

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The impact of tender specifications and evaluation model of the waste collection procurement on the waste collection fees

Jana Põldnurk

***Abstract*—**The current paper analyses the impact of the tender specifications and evaluation model of the waste collection public procurement on quality and waste collection fees of the organised waste collection service in Harju County municipalities. The tender specifications, including service quality requirements, and tender evaluation model are the two key factors which influence the final service quality and price. Since the organised waste collection is a public utility which is organised by local authority and executed by private enterprise, the service quality and price must be fair and reasoned. In the current research a new formula for the formation of the municipal waste collection fees within the organised waste collection scheme (OWCS) is introduced, and the impact of tender specifications on the OWC service is analysed. The OWCS enables the municipality to take more control over the formation of the waste collection service prices, and make the waste collection fees more transparent. Through the optimisation of waste collection routes within OWCS the environmental impact and economical costs of municipal waste transportation can be reduced remarkably. However most of the Estonian municipalities have not occupied this administrative tool effectively. The municipal waste collection fees in most of the municipalities are obscure, unequal, and unreasonable in terms of price-quality ratio of the waste collection service. This is the result of weak evaluation criteria of the waste collection public procurements. The current research gives the municipalities arguments to take more control over the municipal waste collection service.

***Keywords*—**administrative efficiency, municipal waste management, polluter pays principle, public procurement, tender evaluation model

I. Introduction

THE main principles of waste management, such as the waste management hierarchy, polluter pays principle, principles of self-sufficiency and proximity, and producers responsibility are set in the EU waste framework directive [EC, 2008]. Local authorities (LAs) constitute worldwide the main providers of municipal solid waste (MSW) management services, either directly or indirectly through subcontracting part or all of these services [Chalkias and Lasaridi, 2009]. Also in Europe, the municipalities are usually responsible for municipal waste management and its administration, either procuring services or providing services through municipal enterprises. In Estonia, since 2005 the municipalities are obliged to take more control over (= organise and procure) the municipal waste collection service, and since 2010 the National Waste act gives the municipalities the possibility to provide the service administration by themselves [EP, 2004, § 66-1 and §66-1[1]]. The waste companies have been against this kind of reorganisation accounting for and indicating to the potential inefficiency of the municipal enterprise.

Recent empirical research has confirmed that, contrary to common assumptions, there are no significant differences in efficiency between public and private waste operators (empirical studies also find the same result in respect of water, electricity and other sectors). A Spanish-American team analysed all econometric empirical studies of efficiency and privatisation in waste management and in water, and found “no systematic support for lower costs with private production…we do not find a genuine empirical effect of cost savings resulting from private production”. Two of the authors carried out a further empirical study on waste management in rural areas, finding that inter-municipal arrangements reduce costs but outsourcing does not: “small towns that cooperate incur lower costs for their waste collection service. Cooperation also raises collection frequency and improves the quality of the service in small towns. By contrast, the form of production, whether it is public or private, does not result in systematic differences in costs.” [Hall, 2010, p. 10]

As defined in the national Waste Act, the organised waste collection (OWC) 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. The local authority holds a concession of services procurement to select the waste collection service provider, and determines the waste treatment facility. As the result of the public procurement, a waste collection service provider enter into contractual relationship with the local authority up to five years. All households are required to join the waste collection system. The size of the waste collection district should assure the fill up of a waste truck in one collection route but may comprise generally no more than 30,000 inhabitants. The OWCS involves the mixed municipal waste, and the source sorted waste. The local authority must define the principles of pricing the waste collection service in the local waste regulation [EP, 2004].

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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 (WMC), which would then be the only client of the waste collection company, and fully responsible for the waste collection service as an administrative body. In the advanced OWCS the municipality holds separate public procurements for waste collection, and waste treatment services. The municipality bills 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 redirection cash flow from "waste holder → waste company" to "waste holder → WMC → waste collection company, and waste treatment company" enables to integrate some waste management costs (e.g. waste holders register, domestic hazardous waste collection, advising, and awareness raising activities) into waste collection fee as the administrative costs, which disencumbers the municipality's budget from those expenses. The two main differences of the advanced OWCS compared to the regular OWCS are the redirection of the cash flow, and separation of the waste collection, and waste treatment services [Kivimägi and Loigu, 2013].

The principles of waste collection service pricing set in the local waste regulation, and tenders evaluation model of the waste collection service concession procurement are the key factors which create the base for the fair, and transparent formation of the waste collection fees. Another key factor is the qualification criteria which limit the circle of tenderers, and in association with the other requirements and conditions of the concession contract assure the quality of the waste collection service. Beside the mixed municipal waste, source sorted paper waste, and bio-waste can be involved to, and centrally collected within the OWCS. Thus, the OWCS, especially the advanced format of it, has given a set of administrative tools to a local authority to organise the environmentally sound, and economically fair municipal waste management on its territory.

A new model for a fair, and transparent formation of the municipal waste collection fees, including the tender evaluation model of the OWC procurement is introduced in the current paper. Also the main tender specifications, and qualification criteria of the OWC procurements which would improve the quality of the OWC service are briefly overviewed, and reasoned. Since the OWC is a public communal service, the main principles of the public procurement including fair competition, contribution to the environmental sustainability, transparency of the evaluation criteria etc., must be applied to the OWC public procurements.

The analysed data involves the databases of the waste holders' registers of the Harju County municipalities, the tender evaluation models of the last OWC procurements [Kivimägi, 2011], and waste collection fees in those municipalities [Kivimägi, 2012]. In addition, the results of the OWC procurements in some municipalities which have applied the introduced formula were used as examples.

There are several researches aiming to improve the administrative and economic cost-efficiency, and to reduce the environmental impact of the municipal waste management applying different info-technological tools and models. These researches involve GIS (Geographic Information System), DSS (Decision Support System), IWMM (Integrated Waste Management Model), NPV (Net Present Value), LCA (Life Cycle Assessment), PAYT (Pay As You Through). GIS was used to improve the efficiency of waste collection and transport in the Municipality of Nikea (MoN), Athens, Greece via the reallocation of waste collection bins, the introduction of new vehicle routing and new vehicle time [Chalkias and Lasaridi, 2009]. Xiangyun *et al.* 2007 presented the development of DSS, which elaborates on the construction of databases, the evaluation model using NPV, and the development of system to assess effectiveness and profitability of any technological process and to find a cost effective model solution in municipal solid waste management [Xiangyun et al, 2007]. Hrebicek and Soukopova, 2010 applied environmental modelling, particularly modelling of Integrated Municipal Solid Waste Management Systems (IWMM) at the Czech Republic to simulate the different scenarios of prescribed waste landfill fees, an inclusion or an exclusion of certain facilities of energy recovery / mechanical-biological treatment of waste with prescribed annual capacity in selected locations [Hrebicek and Soukopova, 2010]. The economical feasibility of the reorganisation of municipal waste collection service in Harju County was assessed by calculating NPV and expanded financial NPV of the different waste management scenarios [Kivimägi and Loigu, 2013], [Järve, 2011]. Moora, 2009 applied LCA to evaluate the environmental impacts of different waste management scenarios regarding the municipal treatment options [Moora, 2009]. The PAYT system applicability in Estonia was analysed by Voronova in her PhD thesis [Voronova, 2013]. All the works conclude in common statement: municipal waste management is a field of activity which comprises a remarkable environmental impact and economic expenses which can be reduced by optimisation of the waste collection and treatment system.

Based on the work experience at the Environmental Department of Tallinn City Government, the author confirms that the implementation of the OWCS (organising public procurements and managing the concession contracts, keeping waste holders register, advising waste holders, supervisory on waste holders) in a municipality comprising nearly 420,000 inhabitants needs a full-time work load of six chief officers, and 0.5 part-time work load (management, coordination) of the head of the waste division in the Environmental Department and one officer (dealing with the exemptions, advising and supervisory) in each city district (8), estimatedly total 14.3 full-time work $(6 + 0.5 \cdot (1 + 8) = 10.5)$ loads which makes 0.025 workloads per 1,000 inhabitants. Thus the administrative efficiency per capita is 4.4 times lower in Harju County compared to Tallinn City [Põldnurk, 2014]. In the current research, the options for improving the administrative efficiency through the conjoined transboundary waste collection procurements are also observed.

II. The practice of the OWCS in Estonia

Since 2004 when the local authorities in Estonia started to change over from the free market model to the OWCS, the waste collection service public procurements have been continuously accompanied by trials, contentions, and complaints. It has been a common practice that as soon as a public procurement in any local authority has been announced, one or another waste company, a potential tenderer sues the municipality. Over 150 adjudications regarding the OWCS can be found in the Database of the Court Decisions, most of them solving cases the waste company versus municipality [Court Decisions, 2014]. The concealed reason for this kind of counteract is to maintain the market share, and delay the implementation of the OWCS. The counteraction on re-municipalisation and municipal interaction on the waste collection market has been practised by the waste companies also elsewhere in Europe.

The town of Lodeve, near Montpellier, decided to terminate the street-cleaning contract of Nicollin and re-municipalise the service from the end of 2009. The company's workers went on strike, protesting that they would lose their jobs and their pay would be reduced; but returned to work after a meeting with the mayor. The city council estimated that the re-municipalisation would save €202,000 Euros in 2010 and €153,000 Euros in 2012 ("cette reprise en régie devrait se traduire pour l'année 2010 (avec trois CAE) par une économie de 202,000 euros et pour 2012 (après titularisation des CAE) par une économie de 153,000 euros."). In 2008 the city of Paris also decided in favour of direct labour for effuse collection, by cancelling plans to contract out two of the districts of Paris (IX e et XVI e arondissements). The city of Marseilles nearly did the same thing. The service in the centre of the city has been operated by a Veolia affiliate, Bronzo. The city council decided that their contract would be terminated, and drew up tender documents to invite bids from other companies, with Veolia debarred from bidding. In reaction to this, Veolia employees went on strike, in protest at the company being excluded, and demanding to be transferred with full protection for their pay. After a week of the strike, the council first cancelled the call for tenders, and then proposed to simply re-municipalise the service – not only in this area, but in all other areas of the city operated by contractors. In November 2009 the socialist president of Marseille council proposed re-municipalising refuse collection in all areas of the city, but in early 2010 the council voted narrowly to continue to contract-out the service, as there was not sufficient time to set up a regime before the current private contracts expire [Hall, 2010, p. 10].

It is obvious that the waste collection public procurements result in the tight pricing competition between the tenderers, and the municipality's control over the waste collection fees. In many cases the subject of the claim are tender specifications which are referred as stipulations limiting the circle of the tenderers, and the evaluation model which make the result of procurements. The most common evaluation criteria in the OWC procurements is 100% price criterion, meaning the lowest price offer wins the procurement. Since the waste collection service involves a set of fees for different types of containers with different numbers of emptying, all the evaluation models which do not consider the whole cost of the waste collection service, in other words the sum of money collected from the waste holders, can be qualified as inadequate type of tender evaluation model for this kind of service because they only reflect the pricelist of the different parts of the service not the whole cost.

A research on procurement outcomes for waste collection systems in the UK market in the period of April 2008 to February 2012 was carried out by 4R Environmental Ltd. This work examines the results of tenders over the mentioned four years to throw light on the actual, rather than theoretical, results when systems are tested in open competition situations. The research looked at the type of procurement: restricted or dialogue; whether there was a prescribed system in the process or whether alternative systems were sought or could be bid; what the outcome was; and who won what, where and when. In total, 65 procurements are included. In more than half, the system outcomes were largely predetermined by the procurement itself. In 29 cases there was a genuine opportunity for alternative options to be explored and a contract award resulted. The outcome of these should be of most interest to local authorities contemplating their procurement options. Most procurement seeks the most advantageous economic outcomes, and whilst cost is not the only determinant, it is most likely that as a whole the winning systems generally proved to be the most financially competitive. Many of the Council reports reviewed indicate that this was indeed the case. Restricting competition has always been a feature in avoiding outcomes that might not suit perceived interests [4R Environmental, 2012].

The OWC service procured by the Estonian municipalities involves both the collection and treatment (either recovery or disposal operations) of mixed municipal waste, and in many cases collection and treatment (recovery operations) of source sorted paper and cardboard and/or bio-waste. The two different services – waste collection and treatment – which require essentially different equipment and competence are mingled into one service. Within 9 years and two or three rounds of the OWCS procurements practice this has delivered to the situation where instead of 13 tenderers (the first OWC procurement in Tallinn, authors practical work experience, 2005) only 3 competitors have left on the municipal waste collection market who are capable for fulfilling the qualification criteria of the OWC procurements. Two out of these three companies (Ragn-Sells and Eesti Keskkonnateenused (EKT, former Veolia Group enterprise) possess the recycling, recovery and/or disposal facilities, which gives them the opportunity for cross-subsiding between transportation and treatment services. These two companies have stocked up the rest of the smaller waste collection companies. The cross-subsiding between transportation and treatment of municipal waste is not directly restricted, however it is against the requirement of the Waste Act § 66 art. 5 according to which the waste collection fee must be sufficient to cover the costs of establishment, operation, closedown and after-care of the waste treatment facility, and also the costs of preparation the transportation (administration, customer service, accounting, etc.) and transportation costs.

Swedish legislation places the responsibility for dealing with solid household waste on municipalities, but leaves it up to the municipalities to decide how to execute this responsibility and organise the management of waste. Three out of four Swedish municipalities contract the collection of household waste to external actors; however, most municipalities process waste internally, either through municipal waste management departments or municipal waste management companies that are fully-owned by a single municipality or a collection of municipalities. The consequence of the Swedish legislation on waste is that municipal waste management companies enjoy a monopoly on household waste within the jurisdiction of the municipalities that own them. Municipal waste management companies are subjected to strict pricing practices, even if only a few fully respect the existing legislation that the confederation of Swedish enterprise demands. Municipal companies have to follow the so-called prime cost price and may not levy charges exceeding the cost of the services or utilities that they provide (SFS, 1991:900); neither are the companies allowed to engage in activities in competition with other companies at a loss. Practices of cross subsiding competitive activities with resources from regulated activities are therefore strictly forbidden, and something that is carefully monitored by municipal owners, competitors and competition authorities alike [Corvellec et al, 2011].

The most common evaluation model practiced in the Estonian OWC procurements is the merit-point system (MPS), in which different values are given to different types of containers, thus affecting the tenderers' pricing strategy. For example, if more merit points are attached to the smaller containers (e.g. 80 to 240 litres) compared to the bigger containers (e.g. 600 to 800 litres) then naturally the pressure is on the collection fees of the smaller containers. This may result in the situation where the collection fees of those containers are lower than their net value, and the collection fees of bigger containers which earned less merit points are remarkably higher than they would be in the free market. Then the whole pricing policy bases on the cross-subsiding between small, and big containers, meaning the users of the big containers will pay for the waste collection of users of the small containers. In a settlement of high population density the whole scheme works in opposite way: higher merit points are attributed to the bigger containers, and lower weighs to smaller containers. The most drastic examples of the MPS practice are cases where the collection fee of a smaller container is higher than that of a bigger container (e.g. 2.70 € for a 240 litres container versus 1.94 € for a 600 litres container) [Kivimägi, 2014]. The whole scheme is at variance with the polluter pays principle, and gives enough ground for suing the procurements. Therefore a strong need for an adequate evaluation model which enables a fair, and transparent pricing policy has been present already for few years.

Another issue regarding the OWCS in Estonia is the size of the waste collection districts. The restriction arising from the Waste Act on the number of inhabitants a waste collection district may involve is 30,000. There are only 5 cities out of total 215 local authorities which number of inhabitants exceeds 30,000 (Tallinn, Tartu, Narva, Pärnu, Kohtla-Järve) [KOP, 2013]. Most of the waste collection districts in Estonia are formed on the basis of the administrative territory, and 70% of municipalities have less than 4,000 inhabitants. Only in few regions the municipalities have cooperated to form conjoined waste collection districts which then comprise a reasonable number of inhabitants. There are 6 regional cooperation organisations (Central Estonian WMC, Eastern Estonian WMC, Rapla County WMC, Valga County Environmental Services Centre, Hiiumaa County Council, Communal Services Center of Harju County), which have successfully formed conjoined waste collection districts, and few other cooperation attempts between some municipalities to form transboundary waste collection districts, comprising altogether approximately 300,000 inhabitants in about 30 districts from about 100 municipalities [Kivimägi, 2014]. Thus, the average size of a conjoined waste collection district is 10,000 inhabitants, which is still far smaller than eligible. The bigger waste collection districts are obviously more attractive to the tenderers, and motivate to offer lower waste collection fees at the public procurements. The bigger collection districts also enable to optimise the waste collection logistics and thus decrease the environmental impact of the waste transportation.

The solid waste collection logistic costs play a major role in the total solid waste and disposal costs, which approval by many researches. Therefore, solid waste logistic costs model which consider most logistic activities as costs and environmental impact help to improve the solid waste supply chain and minimize the city budget for waste management activities. The model presents a reasonably effective way to predict the fuel consumption; distance travelled for waste collection in different area with different collection intervals within alternative network option. The results from those different models give a different investigation but all the result show that the vehicles and man power play a big role in the waste logistic costs [Rhoma et al, 2010].

III. Tender Specifications, and the OWC Contract Conditions

The common practice in Estonia is that the conditions and requirements of the OWC contract to be signed between the municipality (or the authorised non-profit organisation), and the public procurement winner waste company are mostly described as the tender specifications. The usual qualification criteria involve fulfilling the tax duties, and absence of criminal or professional records. Commonly the possession of the waste collection/treatment licence, experience at the waste collection market (usually at least equal to the service volume of the waste collection district), and sometimes the certificate of the environmental quality management (ISO, EMAS or equal) are required.

In Romania the organisations that want to implement a waste management system should participate directly in the preservation, protection and improvement of environment by making decisions in accordance with the requirements of environmental protection; prevent pollution and damage towards the environment; maintaining and improving the environmental quality; establish a system for monitoring of environmental factors; sustainable use of resources and environment, and; creating of ecologically and informative program aimed at regional level. 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 reduce costs of any environmental incidents [Dumitrascu and Nedelcu, 2012].

The conditions of the OWC contracts may vary at a large scale from municipality to municipality from detailed description of the waste collection service, and from strict technical requirements to a very general conditions such as that the municipal waste must be collected from households and treated somewhere [Kivimägi, 2014]. The conditions introduced, and reasoned below are suggested by WasteBrokers LLC. Those conditions may rise the waste collection fees but are necessary for the municipality in order to gain better control over the waste collection service. The following list of the conditions is not final, only the major conditions are disserted. Most of the requirements have arisen from the practical experience of the OWCS, step by step evolved from execution of one or another OWC contract.

A. Technical specifications

1) waste trucks must be passed through the technical inspections, and be technically in order;
2) waste trucks may not be older than e.g. 10 years, or must meet the EURO IV requirements;
3) waste trucks must be provided with the utilities/repellents to clean up any waste spilled during emptying containers or driving, also the absorbent to clean up any liquid waste;
4) waste trucks must be provided with the GPS-device, mobile phone, and camera, also the rechargers of the devices. GPS must register the emptying of the container and keep the record of the movements of the waste truck;
5) waste trucks must wear the label of the company, and the contact information, the drivers must wear the uniform;
6) waste containers hired out must meet the standards, be labelled, and in fine condition.

It is natural that only trucks which are legally, and technically in accord may participate the competition. In order to contribute to the sustainable development, and reduce the environmental impact of the waste transportation, the requirements on the exhaust gases are imposed. The equipment for spillage clean up mitigates the pollution risk. The GPS-device, mobile phone, and camera are necessary in case of conflicts between the waste holder and waste contractor, e.g. if the container contains improper waste, and is left unemptied, the contractor can immediately contact the client, and inform about the situation, and also record the situation with the camera. GPS-device enables to track the itinerary of the waste truck. The containers hired out by the contactor must meet the requirements of the local waste regulation, and be labelled with the requisites of the contractor.

Most of those criteria rise the quality standard of the waste collection service, which may result also in higher waste collection fees. For example, a GPS-device, phone, and camera are not essential for the waste collection service, but facilitate solving any communication problems increasing the satisfaction of the clients. The environmental requirements which are stricter than set in national or EU legislation serve mostly the objectives of sustainable development.

B. Service quality

1) customer service must be available by phone, e-mail or counter service;
2) reaction to the complaints, orders or subscriptions may not take longer than e.g. 3 working days;
3) contractor must inform the client about any circumstances which make the waste collection impossible, such as absence of access to the waste container (the container or gate is locked, the gateway is impassable), improper waste in the container like bio-waste in the paper container, broken container etc.;
4) contractor must provide the waste holder with the necessary number, and types of waste containers for each waste classes, and adjust the container emptying frequency according to the waste generation of the particular waste holder;
5) contractor must clean up any spillage caused during emptying the waste container or waste transportation.

The service quality stands mostly on the conditions set on the OWC contract. Since the waste company gains the monopoly for the period of the OWC contract, there is no pressure of competition like it was at the free market conditions, and the exclusive position may result in a loose quality of the service. In the very first OWC contracts, merely any requirements were set on the customer service, and communication. For example the implementation of the OWCS in Tallinn pilot districts was accompanied by extensive displeasure of the waste holders caused by the miscommunication, and poor quality of the customer service. Although the containers are not involved to the OWCS, in the case of need the contractor must be capable of providing the waste holders with the containers. It is also natural, that after waste collection the area is still clean and free of any spillage caused by the emptying waste containers or transportation of the waste.

C. Reporting

1) contractor must keep minimum for three months all the recordings, files, e-mails, and photos regarding the communication with the clients, including tracks of any

conflicts appeared during providing the service;

2) contractor must periodically (monthly/quarterly/annually) fill a detailed report about the waste collection service performance which presents the volume and weigh of the waste collected and treated, mileage of the waste trucks, number of emptyings per each type of containers, overview of the complaints from the waste holders etc.;
3) contractor must keep the waste holders register, and periodically update the database. The register comprises the following data: addresses, and names of the waste holders; status of the waste holders (incorporated to the OWCS, exempted from the OWCS); number, and types of the containers for each waste classes; emptying frequency of the containers; overdues, and indebtnesses; other records;
4) contractor must inform the municipality about any violation of the local waste regulation requirements which the contractor finds out.

The demand for maintaining the records for a certain period helps to solve any conflicts or misunderstandings between the contractor and municipality or waste holder. The detailed reporting about the waste collection service in particular waste collection district give the municipality not only overview about the waste collection service but also a good input data for the next public procurement. The more precise input data about the service is given in the tender specification, the more fair is the competition, and the more judicious tenders will be made. The waste holders register is a good virtual tool for supervisory and statistics if the data is periodically updated.

D. *Additional conditions*

The prices of those services which are not involved to the OWCS but are inseparable for the regular waste collection such as the rental of the waste containers, unlocking the containers or gates with the waste holder's key, manual transportation of the containers from a certain distance (10 or more metres) to the closest possible stop of a waste truck, washing the containers etc., are fixed.

Many local authorities have demanded the bank deposit or accreditation letter from a bank to warranty the accomplishment of the contract conditions. However none of the municipalities have ever tried to put this type of warranty into practice. Thus it may be a pretty much useless condition which only rises the price offer because it is costy to the tenderer.

The contractor may not rise the waste collection fees without the permission of the municipality. The waste collection fees will be risen only if the direct expenses (such as the price of fuel, gate fee of the waste treatment facility) of the waste collection service have increased. This condition can be implemented only if the components of the waste collection fee are clearly defined or separable. Otherwise the condition is not objective. Another option practiced widely is the fixed pricing for the whole contract period without any possibility to rise the collection fees.

The collected waste must be delivered to the waste treatment facility determined by the municipality. This condition is taken from the Waste Act literally, but interpreted arbitrarily by both the municipalities, and waste companies, and has been one of the reasons for prosecutions. As the waste companies have declared, this condition is limiting the freedom of entrepreneurship. The municipalities who have not appointed a particular waste treatment facility but outlined the condition generally cannot gain any control about the recycling or recovery of the municipal waste later during the concession period neither.

By the end of the contract the contractor must give over the upgraded database of the waste holders register, and not counteract to the next contractor overtake the waste collection district. The contractor has to update the data of the waste holders register, and give it over to the municipality.

In order to improve the waste collection efficiency in the detached houses areas, the municipality obliges or suggests the waste holders to place the waste bins along the street on the day of waste collection. This eases the manual transportation of the bin from its location to the waste truck, and thus fastens up the waste collection speed rate. The time of the stops of the waste trucks are shortened, the exhaust gas emissions are cut and the environmental impact arising from the transportation is also decreased.

The research of Chalkias and Lasaridi, 2009 aimed to develop a methodology for the optimisation of the waste collection and transport system based on GIS technology. The methodology was applied to the Municipality of Nikea (MoN), Athens, Greece based on real field data. The strategy consisted of replacing and reallocating the waste collection bins as well as rescheduling the waste collection via GIS routing optimisation. The benefits of the proposed strategy were assessed in terms of minimising collection time, distance travelled and man-effort, and consequently financial and environmental costs of the collection system. In this study GIS technology was used for the optimisation of commingled municipal solid waste collection. The proposed method exploits various geographical data (road network, waste collection bins' position, land use etc) in combination with advanced GIS based spatial analysis. The implementation of the proposed method in MoN focused on the re-design of the waste collection bins system as well as on the investigation of an optimal collection routing scenario. The 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 [Chalkias and Lasaridi, 2009].

IV. The Equations for Waste Collection, and Treatment Fees

The equation for OWC service fee, including formulas of waste collection fee, and waste treatment gate fee introduced below is worked out by WasteBrokers LLC basing on different common tenders evaluation models. The formulas are used for evaluation of the tenders at the OWC service public procurement. All the components of the waste collection, and treatment service (collection, and administration, transportation, and treatment) are taken into account separately. This enables to change/recalculate them independently during the period of contract. The evaluation model for waste collection service has been practiced in some of Estonian municipalities [Põltsamaa, 2011], [HÜK, 2013], and has given clearly positive results in terms on transparency of the price formation, and comparison of the tenders. The whole set of equations (collection, and treatment service separately) has not been practiced yet, but the legislative prerequisites are created in the local waste regulations of few municipalities [Tartu, 2012], [Viljandi, 2011], and the evaluation model will be implemented in the next round of the public procurements which will be held before the current waste collection contracts end, perspectively within next couple of years.

Only the equations for mixed municipal waste fee is introduced below because the paper waste is usually collected free of charge if the waste collection company retains the possession of the paper waste, and the equations for the source sorted bio-waste are identical, ant the amounts of this waste are marginal.

A. The collection fees

The tender evaluation criteria at the public procurement of the OWC service concession is 100% price criteria. The tenderers offer the collection fees (€) for the different size groups, and types of waste containers indicating separately the calculated percentage of transportation costs within the collection district, and transportation from the collection district to the determined waste treatment facility. Then the annual waste collection fee is calculated for each group of containers multiplying the collection fee by the number of emptyings per year, and the annual cost of the collection service is calculated as follows:

$$K_A = (K_{M1} \cdot E_{M1}) + (K_{M2} \cdot E_{M2}) + (K_{M3} \cdot E_{M3}) + (K_{M4} \cdot E_{M4}) \quad (1)$$

where

K_A – total annual collection fee;

K – collection fee for particular type of container;

E – number of emptyings of particular type of container a year;

$M1$ – type of container, e.g waste bag with volume of 50...100 litres;

$M2$ – type of container, e.g small two wheels container with volume of 80...400 litres;

$M3$ – type of container, e.g four wheels container with volume of 600...1,100 litres;

$M4$ – type of container, e.g container without wheels, deepload containers etc. which need special mechanism for their emptying.

The best tender is the one which sum of the annual collection fee (K_A) is the smallest. The grouping of containers may differ in municipalities depending on what kind of containers are more or less used. The technical parameters such as age of the truck, service quality, reporting, customer service or other determined as the tender specifications, and qualification criteria are not subject of evaluation.

B. The treatment service fee

The evaluation criterion at the public procurement of the municipal waste treatment service is 100% price criterion. The tenderers offer the gate fees (€/t) for treatment (recycling, and recovery operations) of the mixed municipal waste, and indicate the location, and distance of the treatment facility from the collection district. Then the combined gate fee is calculated as follows:

$$CF = L + S \cdot T / w \quad (2)$$

where

CF – combined gate fee (€/t);

L – gate fee at the treatment facility (€/t);

S – the shortest distance for fully loaded waste trucks between the treatment facility, and collection district (kilometres);

T – transportation cost, constant 1 €/km;

w – weight of the load, constant 8 tons.

The best tender is the one which combined gate fee (CF) is the smallest. The technical parameters such as the rate of recycling or recovery, annual capacity, and other environmental requirements determined as the qualification criteria are not subject of evaluation. The combined gate fee enables to consider the transportation costs in the collection fee, and are used only for evaluation model. The contractor will receive only the offered gate fee for his service.

C. The OWC service fee

The final OWC service fee of a mixed municipal waste container is calculated as follows:

$$T_m = K_m + k \cdot m \cdot L\ (\cdot J_m) \quad (3)$$

where

T_m – the fee (€) for collection, and treatment for waste contained in particular container (€);

K_m – the collection fee (€) for the waste contained in particular container which includes the costs of waste transportation from waste generation site to the waste treatment facility, costs of fuel, logistics, preparation of the waste collection, and other costs of waste collection company directly linked to the OWC service, except the costs of other additional services not involved to the OWCS such as rental of the container, unlocking the container or gate, transportation of the container from further than 10 metres, container wash etc.;

k – the coefficient of the volume weight of the mixed municipal waste (t/m^3) which is determined separately for each municipality, and procurement (usually in range of 0.13…0.17), and which the municipality has right to change if during the concession contract occurs that the real volume weight differs from the agreed one;

m – the volume of the container (m^3);

L – the gate fee for the mixed municipal waste (€/t) at the determined waste treatment facility;

J_m – administration fee coefficient which the WMC or municipality has right to apply in case of implementation of the advanced OWCS; it is a cost-based coefficient, which includes the municipality's/WMC/s expenses directly linked to the administration, and organisation of the OWC, such as salaries of the officers, keeping, and development of waste holders register, accountancy, and bookkeeping of the OWC, including rescontra, and incasso, logistics, customer service, and call centre (either within WMC or procured).

V. Results and Discussion

As the result of application of above introduced formulas, the annual turnover within OWC service is calculated for each tenderer based on their price offers. Then the final numbers – the annual turnovers – are compared and the tender with the smallest annual turnover is announced as winner. This means that not any abstract pricelists are competing but the real (annual) cost of the whole service is calculated. This is an important difference between the introduced tender evaluation model and all the rest of the OWC tender evaluation models applied in Estonia theretofore. Another important property of this evaluation model is that it takes into account the collection and treatment costs separately, and the collection fees are proportional to the sizes of the containers.

Below the comparison between annual turnovers of the mixed municipal waste collection within previous and current OWC service is drawn by case of four municipalities in Harju County, which recently applied this tender evaluation model – Jõelähtme, Kiili, Raasiku and Rae parishes. The procurement was organised by the Communal Services Center of Harju County (Harjumaa Ühisteenuste Keskus, HÜK) which was established as the result of a project [Kivimägi and Loigu, 2013], [Põldnurk, 2014], and this procurement was its first attempt towards the advanced OWCS. In addition to applying the new tender evaluation model, the four municipalities formed a conjoined waste collection district for the new OWC procurement.

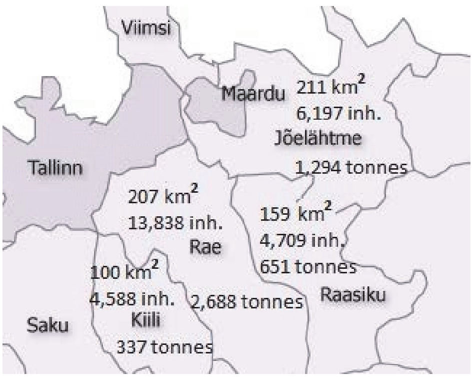

Fig. 1 The map of the four parishes [Kivimägi, 2012].

A. The input data

All the four parishes are neighbouring, they have prevailing rural areas scattered with settlements and village centres with higher population density. The number of inhabitants vary from 4,588 to 13,838, sizes of the territories from 100 to 211 km^2 [KOP, 2013] and mixed municipal waste (MMW, code 20 03 01 by List of Wastes [EC, 2000]) generation from 377 to 2,688 tons per year [EEIC, 2012] (Fig. 1). Thus their administrative-territorial profile is relatively similar.

Table 1. Number of MMW containers' emptyings in the four parishes and in the conjoined waste collection area [Kivimägi, 2011], [HÜK, 2013]

Con-tainer	Jõe-lähtme	Kiili	Raasiku	Rae	Con-joined
100 L*	117	5384	100	687	6288
80 L	4347	26	19	38	4430
140 L	3865	3265	1300	6001	14431
240 L	7046	13740	2556	17190	40532
370 L	958	939	440	2720	5057
600 L	2646	1393	3031	6205	13275
800 L	1990	1493	1827	5962	11272
1000 L	352	821		985	2158
2500 L	878	378	679	1845	3780
4500 L	365	52	286	798	1501
*waste bag					

Table 2. Pricelist (V.A.T. not included) of MMW collection service 2011 (4 parishes) and 2013 (conjoined) [Kivimägi, 2012], [EKT, 2013]

	Jõe-lähtme	Kiili	Raasiku	Rae	Con-joined
Con-tainer	Ragn-Sells	Ragn-Sells	Veolia	Adelan	EKT
100 L*	1,03 €	0,96 €	0,92 €	1,00 €	0,44 €
80 L	1,00 €	1,13 €	1,54 €	1,16 €	0,31 €
140 L	1,56 €	1,13 €	2,15 €	1,62 €	0,52 €
240 L	2,94 €	2,05 €	4,14 €	2,70 €	0,87 €
370 L	3,07 €	3,05 €	4,52 €	2,98 €	1,33 €
600 L	3,58 €	3,45 €	7,02 €	1,94 €	2,35 €
800 L	4,28 €	6,50 €	11,51 €	3,24 €	2,84 €
1000 L	5,35 €	8,13 €	n/a	4,05 €	3,88 €
2500 L	10,89 €	9,35 €	18,41 €	7,15 €	8,80 €
4500 L	17,90 €	16,45 €	32,21 €	12,78 €	15,82 €
*waste bag					

Table 3. Annual turnovers (V.A.T. not included) of MMW collection service 2011 and 2013 (conjoined) [Kivimägi, 2012], [EKT, 2013]

Container	Turnover 2011	Turnover 2013
bag 100 L	5 380,97 €	2 766,72 €
80 L	4 405,56 €	1 373,30 €
140 L	22 232,87 €	7 504,12 €
240 L	105 877,08 €	35 262,84 €
370 L	15 901,17 €	6 725,81 €
600 L	47 593,85 €	31 196,25 €
800 L	58 563,70 €	32 012,48 €
1000 L	12 547,18 €	8 373,04 €
2500 L	38 786,50 €	33 264,00 €
4500 L	26 798,83 €	23 745,82 €
total turnover	338 087,71 €	182 224,38 €

To calculate the annual turnover of the previous OWC contracts the valid pricelists of 2011 [Kivimägi, 2012] and databases of the waste holders' registers [Kivimägi, 2011] were used. Only the Jõelähtme, Kiili and Rae parishes had the valid waste holders' databases which contained the number of waste containers and their emptying intervals. In order to create the missing data of containers and their emptying intervals of Raasiku parish, the data of the three other parishes was extrapolated on Raasiku parish taking into account the average number of inhabitants, population density and waste generation and the sum of emptyings for different types of containers of all the 4 parishes presented in the new OWC public procurement documentation. The results were double-checked by calculating the MMW amounts basing on the number of containers, their emptying intervals and expected mass weigh of 0.13 t/m^3 [HÜK, 2013]. In the table 1 the number of containers in each parish is presented and in the table 2 the pricelist of the previous OWC service is presented.

The pricelist of EKT presented in table 2 is the result of the new OWC procurement in the conjoined waste collection district. The formulas 1 and 3 were applied in order to calculate the best price offer and pricelist for each particular container. The annual turnover basing on the tables 1 and 2 was calculated for the years 2011 and 2013 (table 3). As it can be seen from the table 2 and table 3, cheaper collection fees were achieved in the new OWC procurement and the annual turnover drop nearly twice. This was the result of the remarkable drop of the collection fees whilst the treatment service made up the majority in the total annual turnover. The cost of treatment service was calculated basing on the expected annual waste generation of 5,408 tonnes multiplying it by the offered treatment facility gate fee 27 €/t. The total cost of treatment service was 146,016 euros [HÜK, 2013].

Recent data from the UK also shows that the average net total cost of waste collection is slightly lower (by about 3%) for municipalities which operate an in-house service. Municipalities which outsource appear to have lower current expenditure, but they:

- employ staff costing over 5% of the contract value, to monitor the service
- still pay for capital investments, with more than half of the capital costs of in-house services
- lose income worth more than 7% of the cost of the service.

These factors more than offset the apparent reduction in current expenditure. The apparent cheapness of contractors' operating costs is also frequently due to the low pay of private companies: in Germany in 2011, some contractors paid such poor pay and conditions that their workers claimed benefits. (The German employers and trade union Ver.di have now agreed a minimum wage for the sector that has been declared generally binding, to prevent such cut throat competition) [Hall and Nguyen, 2012].

Despite fiscal pressures, there are clear signs that municipalities are continuing to move towards re-municipalisation rather than privatisation, in a number of countries in Europe, including Germany, France and the UK. A study in 2011 by Leipzig University of over 100 German municipalities concluded that the trend is towards greater provision by the public sector. In his report, Hall, 2012 presents in table the main services and process of the re-municipalisation in different European countries. As to the waste management, the re-municipalisation has taken place in Germany, UK, France and elsewhere through in-house brought contracts, including inter-municipal incinerators involving factors such as cost of service, control, or contract expiry. German municipalities have also been bringing other services back in-house, such as waste management, housing management and public transport: In the history of privatization of local public transport, more often than not, the services provided were reduced dramatically and the prices saw steep increases. Pressure to make cuts still tends to lead to re-municipalisation: half of the municipalities with budget deficits plan some form of restructuring of municipal services, but while 41% of these are considering moving towards inter-municipal cooperation, and 36% towards re-municipalisation, less than 3% are considering privatisation. [Hall, 2012].

VI. Conclusions

The OWCS practice in Estonia theretofore has led to the decrease in number and competition between the waste collection companies, incomprehensible pricing, and sometimes also poor quality of the waste collection service. The cooperation between Estonian local authorities would improve the administrative efficiency and raise the level of competence in the waste management field. In Harju County, the waste management cooperation organisation HÜK has been established and already performed positive result in the OWC procurements.

The formation of the waste collection fees within the OWCS, especially within the advanced OWCS have to be transparent, and fair. A set of equations for the waste collection fees worked out by WasteBrokers LLC enable municipalities to implement the comprehensive tender evaluation model at the OWC public procurements, which creates the equal opportunities to the tenderers, and facilitates the tenders' evaluation process. The implementation of the formulas result in transparent waste collection fees, in which each component is clearly distinguishable, and economically justified. Strict requirements of the OWC contract assure the quality of the waste collection service, and municipality's control over the waste collection fees.

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in 2003-2006, and the head of the division 2007-2010. She worked out the conditions and requirements of the OWCS public procurements including the tender evaluation models. As the head of the division, the waste management planning, development, budgeting and local legislation, administration of the waste holders register and supervisory, awareness raising activities and PR, development of source sorting of recyclables, domestic hazardous waste collection, and post-closedown maintenance of the local landfill were also under her responsibility. She started her PhD studies at the Tallinn University of Technology in September 2009. Since then she has worked as a junior researcher for the TUT Institute of the Environmental Engineering, participating on the INTERREG IV A project "Sustainable utilisation of waste and industrial non-core material (SUSBIO)" and giving lectures on waste management and sludge treatment. Since May 2010, after leaving Tallinn City Government she has worked as a consultant and project manager at Jäätmemaaklerid OU (WasteBrokers LLC). In 2011-2012 she was an expert in the "Development of waste management cooperation in Harju County Municipalities" project. Therefore, all the arguments and conclusions that are not from other authors indicated in the references are based on the practical work experience of the author.

PAPER VI

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Optimisation of the Economic, Environmental and Administrative Efficiency of the Municipal Waste Management Model in Rural Areas

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Abstract. The current paper focuses on the municipal waste management model optimisation in rural areas from the aspect of economic, environmental and administrative efficiency by case of Harju County municipalities in Estonia. The main problems and environmental impacts regarding waste management in rural areas arise from the administrative and logistical inefficiency which are expressed in high waste transportation costs, multiplicity of tasks of the public officers, unclear and unfair pricing formation, and municipality's low control over the municipal waste collection service. Although the waste hierarchy sets the preference of waste treatment operations, the environmental and economic feasibility may shuffle the priorities. In rural areas the transportation has a significant role in the environmental and economic impact of waste collection, and separate collection of some waste classes may turn economically and environmentally unfeasible. The administration of the waste management in the rural municipalities suffers from the lack of competence and financial resources. The objective of the research was to assess 1) the environmental and economic feasibility of source sorting paper and bio-waste in rural municipalities, 2) improvement of administrative efficiency, and economical cost-effectiveness resulting in reorganisation of waste management administration, and 3) optimisation options of the municipal waste collection logistics through inter-municipal waste collection districts. The results of the study show that in rural areas central collection of source sorted bio-waste is not economically and environmentally feasible, however the central collection of source sorted paper waste may be considered environmentally beneficial if applied through inter-municipal cooperation. This research introduces a new approach how to evaluate the potential feasibility of source sorting and central collection of paper and bio-waste in rural municipalities, and reveals the benefits of inter-municipal cooperation in terms of administrative, economical and logistical efficiency improvement. The model is applicable in any rural area where there is a potential for administrative cooperation between municipalities.

Key words: bio-waste, integrated solid waste management, inter-municipal cooperation, municipal waste collection, resource efficiency, source-sorting.

Abbreviations
BW – bio-waste
CHP – combined heat and power
EKT – AS Eesti Keskkonnateenused = Estonian Environmental Services Ltd.
EU – European Union
FNPV – Financial Net Present Value
HOL – Harjumaa Omavalitsuste Liit = Union of Harju County Municipalities
ISWM – integrated solid waste management
MBT – mechanical-biological treatment
MMW – mixed municipal waste (List of Wastes code 20 03 01)
MSW – municipal solid waste (List of Wastes group 20)
OWCS – organised waste collection scheme
PC – paper and cardboard (List of Wastes code 20 01 01)
RCV – refuse collection vehicle
TJTK – Tallinna Jäätmete Taaskasutuskeskus AS = Tallinn Recycling Centre Ltd.
UNEP – United Nations Environment Programme
WEEE – waste of electrical and electronic equipment
WHR – waste holders' register
WMAP – waste management action plan
WMC – waste management (cooperation and competence) centre

Introduction

EU Directive 2008/98/EC (Waste Framework Directive) requires that the waste hierarchy priority order must be followed in waste prevention and management legislation and policy. When applying the waste hierarchy, member states take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste. EU member states must take measures to ensure waste undergoes recovery operations, and develop the necessary collection systems. By the year 2015 separate collection must be set up for at least paper, metal, plastic and glass wastes [EC, 2008a].

These requirements are challenging to meet in rural municipalities, where according to different researches the main costs and environmental load of municipal waste collection arises directly from the transportation, in other words, from the kilometres and time covered by the waste collection trucks [Beijoco et al., 2011; Boskovic et al., 2013; Jalilzadeh and Parvaresh, 2005; Shamshiry et al., 2011]. Another important factor in the waste management is the administrative efficiency, which in rural areas suffer from the multiplicity of the different tasks of public officers and lack of cooperation and financial funds [Järve, 2012; Kivimägi and Loigu, 2013]. This has led to the situation where the rural municipalities in Estonia have no capability to analyse nor improve their waste management performance. The municipal waste collection service is outsourced to private companies under the organised waste collection scheme (OWCS), the service pricing principles are unclear and in some cases even at variance with the law, and usually the municipality has weak control over the service quality.

The integrated solid waste management (ISWM) 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 ISWM; 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. Regarding the UNEP, integrated solid waste management refers to the strategic approach to sustainable management of solid wastes covering all sources and all aspects, covering generation, segregation, transfer, sorting, treatment, recovery and disposal in an integrated manner, with an emphasis on maximizing resource use efficiency [UNEP, 2009]. In the current paper, the integrated system optimisation is carried out in focus of three aspects: (i) examination of the source sorting efficiency and requirements, suggesting rearrangements in the current scheme; (ii) improvement of administrative and economic efficiency through inter-municipal cooperation; and (iii) improvement of the municipal waste collection logistics, cutting the environmental and economic load arising from the transportation by forming overboundary waste collection districts.

The environmental and economic feasibility of source sorting and the central collection of bio-waste (BW) is in focus of the current paper since this is the major fraction (up to 56%) in the mixed municipal waste (MMW) [Moora, 2008 and Moora, 2013] which comprises several adverse impacts (e.g. contribution to the landfill gas and landfill leachate generation) on the environment if not treated properly. Source sorting of paper and cardboard (PC) is in focus of the current paper because of the legislative commitment on separate collection of this waste fraction. The administrative (in)efficiency was analysed in the project "Development of waste management cooperation in Harju County Municipalities" (hereafter: the Project), and the Project results revealed that inter-municipal cooperation would improve both the administrative and economic efficiency, and the quality of the public waste management services. Beside the MMW, source sorted PC, and BW can be involved to, and centrally collected within the OWCS. Thus, the OWCS, especially the advanced format of it, has given a set of administrative tools to a local authority to organise the environmentally sound, and economically fair municipal waste management on its territory. In the advanced OWCS the municipality holds separate public procurements for waste collection, and waste treatment services. This model enables to integrate some waste management costs (e.g. waste holders register (WHR), domestic hazardous waste collection, advising and awareness raising activities) into waste collection fee as the administrative costs, which disencumbers the municipality's budget from those expenses, and mitigates the lack of funds for public waste management services by directly applying the polluter pays principle.

2 Materials and methods

The general input data of the current research were the number of population, size of the territories [KOP, 2014], calculated population density, waste generation of mixed municipal waste (MMW), separately collected PC, and BW [EEIC, 2012], structure of dwellings [Stats, 2011], waste management budgets [MFER, 2012], OWCS contracts validity and contracting parties, number, sizes and emptying intervals of the waste containers (data of waste holders' registers, WHR), and the waste collection fees of MMW, PC and BW. The waste management situation in Harju County municipalities, including the main problems regarding waste management, municipalities budgets and public utilities, source sorting options, status of legislation, validity of the OWCS contracts and contracting parties, waste collection service fees, and databases of the WHRs, was filed by the author in 2011-2012 within the Project using questionnaires and interviews addressed to the waste management officers of the Harju County municipalities, homepages of the municipalities and waste companies, and official database of the waste management permits (http://klis2.envir.ee). The file has been periodically updated by the author, last in April 2014.

In 2012, the Harju County municipalities, excluding Tallinn, comprised about 153,000 inhabitants on 4,175 km^2

[KOP, 2014], the MMW generation was 31,397 tonnes, and in addition 2,094 tonnes of source sorted PC and 1,027 tonnes of source sorted BW was collected [EEIC, 2012]. The OWCS was implemented in most of the municipalities, and even if the OWC contract were expired, the contractor maintained the market share and continued the service providing under same conditions. All together the Harju County municipalities spent 804,727 € on the public waste management services [MFER, 2012], which included management of the public waste stations, and public waste containers (not packaging), domestic hazardous waste collection and treatment, keeping WHR, awareness raising activities, maintenance campaigns, and in some cases also cemeteries' waste management. An average household in Estonia comprises 2.3 members [Stats, 2012].

2.1 Source sorting of bio-waste and paper

In the observed region, Harju County, in most of the municipalities the source separation of some waste classes from the MMW is compulsory. These waste classes are usually packaging waste (code 15 01 06), PC, and in many municipalities also biodegradable kitchen waste (code 20 01 08) or BW in general. In the municipalities where separate collection of PC and BW is compulsory, the central collection of these waste classes is applied in the apartment houses with generally more than 10 flats within the OWCS. Rest of the households are suggested to deliver PC to the public containers, and compost BW on site. The source sorting and central collection of PC and BW was analysed from the aspects of economic and environmental feasibility. As the result of the analysis, suggestions are made for upgrading the source sorting requirements. In 20 municipalities out of 23 separate collection both of paper and BW is compulsory. Most of the BW containers were 0.14…0.24 m^3 with weekly emptying frequency. The typical size of the PC container is 0.6…0.8 m^3 or 2.5 m^3 with fortnightly (14 days) emptying frequency. In the Table 1, the number of buildings with 10 or more dwellings [Stats, 2011], which according to the local waste regulation should have a separate container for BW and/or PC is also presented in comparison of the WHRs' data and waste generation [EEIC, 2012] which reflects the actual situation on source sorting.

Table 1. Separate collection of PC and BW, number of buildings with 10 or more dwellings, number of containers (cont.), calculated service volume (m^3/y), and waste generation (ton/y) in 2012.

Municipality	buildings with 10+ dwellings	waste classes involved to OWCS	PC (20 01 01)			BW (20 01 08)		
			cont.	m^3/y	ton/y	cont.	m^3/y	ton/y
Aegviidu	**	n/a	3	95	0	0	0	0
Anija	45	MMW, PW, BW	n/a	n/a	8	n/a	n/a	0
Harku	63	MMW, PW, BW	111	2 685	125	8	90	51
Jõelähtme	34	MMW, PW, BW	9	137	27	2	8	33
Keila	34	MMW, PW, BW	n/a	n/a	41	n/a	n/a	0
Keila town	90	MMW, PW	n/a	n/a	83	n/a	n/a	0
Kernu	12	MMW, PW, BW	9	657	3	11	454	11
Kiili	9	MMW, PW, BW	41	548	0	14	118	1
Kose	48	MMW, PW, BW	865	1 039	32	43	361	23
Kuusalu	50	MMW, PW, BW	108	2 265	48	46	289	20
Kõue	**	MMW, PW, BW	n/a	n/a	0	n/a	n/a	0
Loksa town	35	MMW, PW, BW	n/a	n/a	15	n/a	n/a	0
Maardu town	120	MMW, PW, BW	n/a	n/a	153	n/a	n/a	47
Nissi	28	MMW, PW, BW	28	372	15	9	71	7
Padise	**	MMW	0	0	0	0	0	18
Paldiski town	38	MMW, PW, BW	n/a	n/a	39	n/a	n/a	91
Raasiku	24	MMW, PW, BW	n/a	n/a	34	n/a	n/a	27
Rae	131	MMW, PW, BW	229	30 768	128	112	534	152
Saku	58	MMW, PW, BW	81	1 655	913	51	329	136
Saue	80	MMW, PW, BW	n/a	n/a	135	n/a	n/a	275
Saue town	34	MMW, PW, BW	20	512	80	32	369	37
Vasalemma	28	MMW, PW, BW	n/a	n/a	29	n/a	n/a	24
Viimsi	79	MMW, PW, BW	n/a	n/a	185	n/a	n/a	76
Harju TOTAL	1 066		1 504	40 734	2 094	328	2 621	1 027

* joined Kose parish in 1.1.2014

** share of 26 buildings with 10 or more dwellings

The service volume of source separated PC and BW presented in Table 1 was calculated basing on the WHRs data as following:

$$V = f_1 \cdot [(n \cdot M_1) + (n \cdot M_2) + (n \cdot M_3) + \ldots + (n \cdot M_x)] + f_2 \cdot [(n \cdot M_1) + (n \cdot M_2) + (n \cdot M_3) + \ldots + (n \cdot M_x)] + f_3 \cdot [(n \cdot M_1) + (n \cdot M_2) + (n \cdot M_3) + \ldots + (n \cdot M_x)] \quad (1)$$

where

V – total annual service volume;

f_1 – number of container emptyings a year, weekly frequency = 365/7;

f_2 – number of container emptyings a year, fortnightly frequency = 365/14;

f_3 – number of container emptyings a year, monthly frequency = 365/28;

n – number of containers;

M_1 – size of the container, 0,08 m^3;

M_2 – size of the container, 0,14 m^3;

M_3 – size of the container, 0,24 m^3;

M_x – size of the container up to 4,5 m^3 in case of PC.

In order to double-check the validity of the WHRs' data on BW containers, the bulk density (BD) of the BW was calculated as follows:

$$BD_B = T_B / V_B \quad (2)$$

where

BD_B – bulk density of BW, kg/m^3;

T_B – annual BW generation, kg;

V_B – annual service volume of BW collection, m^3.

The statistical records of separately collected PC and BW do not exactly match the administrative scheme, meaning in few municipalities the PC or BW is collected separately even if it is not involved to the OWCS, or vice versa, although involved to the OWCS, no records of separately collected PC or BW were found in official statistics. The data of BW containers was counted relevant on the basis of realistic bulk density, which in case of BW was around 290…600 kg/m^3 [Sundberg et al., 2011; WRAP, 2009]. Only in 3 municipalities (Harku, Rae, Saku parishes) the BW bulk density was within the limits. In 6 municipalities (Kernu, Kiili, Kose, Kuusalu, Nissi parishes and Saue town) the calculated bulk density of BW was smaller than 100 kg/m^3, meaning the emptied containers were half-empty. In one municipality (Jõelähtme parish) the calculated bulk density was more than 4,000 kg/m^3, meaning the BW was probably collected directly from enterprises which were not reflected in the WHR. This indicates, that the municipalities have not implemented the source sorting strictly, and the waste companies provide the municipalities with partly irrelevant data of the WHRs. Therefore the approach of potential sorting of PC and BW was applied in the current analysis.

The potential volume and turn-over of the service was calculated basing on equation 1 and average collection fees. The number of buildings with 10 or more dwellings was taken as the minimum number of containers in a municipality, the container with size of 0.14 m^3 was taken as the typical bin for the BW with weekly collection frequency; the container with size of 0.8 m^3 was taken as the typical container for the PC with fortnightly collection frequency. The emptying fees (V.A.T. not included) of the BW containers in Harju County fluctuate from 0.00 € to 5.75 €, in 8 municipalities it was zero, and in Keila and Viimsi parishes the pricelist for BW containers was missing although the service is involved to the OWCS. The PC collection is not free of charge in all the municipalities, in 11 of them the prices (V.A.T. not included) vary from 0.01€ to 27.40 €, in one municipality it is -3.40 €, meaning the waste company is paying to the waste holder for the PC. The average price for 0.14 m^3 BW container emptying was 1.28 €, and 1.71 € for 0.8 m^3 PC container emptying.

The minimal fuel consumption was calculated basing on the distances between towns and village centres, where the separate collection of PC and BW should be applied. The current market share was taken into account in formation of the basic collection routes on http://maps.google.com website. Three simplified routes were drawn of the map, with the beginning from the waste collection company's depot, passing through the every next closest village centre or town, and with the end in case of BW from the treatment facility back to the depot, and in case of PC straight back to the depot as follows:

Route I, EKT, 221 km: Artelli Str, Tallinn – Tabasalu – Harku – Keila – Rummu – Nissi – Saku – Kiili – Jüri – Raasiku – Viimsi – TJTK composting field (Rebala) – Artelli Str, Tallinn [Google Maps, 2014a];

Route II, Ragn-Sells, 176 km: Suur-Sõjamäe, Tallinn – Laagri, Saue town, Paldiski town, Padise, Maardu town – TJTK composting field (Rebala) – Suur-Sõjamäe, Tallinn [Google Maps, 2014a];

Route III, Radix, 123 km: Kose – Kehra – Kuusalu – Kiiu – TJTK composting field (Rebala) – Kose [Google Maps, 2014a].

The routes were drawn along the roads only, the streets in the towns and village centres were not included in this case. However, the specified routes which include the collection within the settlements can be drawn basing on the data of the Register of the Roads, which presents separately the longitude of roads in a municipality and streets in the villages and towns in the municipality [Teeregister, 2012]. In the current analysis the aim was to calculate the very minimum transportation costs, thus the time and distance spent on travelling within the actual collection area was not taken into account.

The fuel consumption was calculated basing on two empirical researches: Entec (2010) and Nguyen and Wilson (2010). According to Entec, an average multi modal compaction refuse collection vehicle (RCV) which travelled 7.47 miles for collection a tonne of waste consumed 8.41 litres [Entec, 2010], which makes 1.13 L/mile or 0.7 L/km. According to Nguyen and Wilson (2010) a co-collection and the normal garbage packer RCV consumed approximately 1.8 L and 1.26 L of diesel per km, respectively, while travelling within the collection areas [Nguyen and Wilson, 2010]. In order to restrain on the minimum expenses, 0.7 L/km was taken as base fuel consumption. Then the feasibility of source sorting and central collection of BW and PC, both from economic and environmental aspects is assessed in section 3.1.

2.2 Inter-municipal cooperation

There are 6 regional cooperation organisations (Central Estonian WMC, Eastern Estonian WMC, Rapla County WMC, Valga County Environmental Services Centre, Hiiumaa County Council, Communal Services Center of Harju County), which have successfully formed conjoined waste collection districts, and few other cooperation attempts between some municipalities to form transboundary waste collection districts, comprising altogether approximately 300,000 inhabitants in about 30 districts from about 100 municipalities. The cooperation involves only some of the tasks listed below (usually the OWCS related tasks, and drafting the WMAP and waste regulation), although there is potential for more cooperation and competence.

According to the Waste act, a local authority is responsible for the development of the waste management, including awareness raising activities (§ 12), compilation of the local waste management action plan (WMAP) (§ 42) and local waste regulation (§ 71), organising the source sorting and recovery of the source sorted waste (§ 31), managing the domestic hazardous waste (§ 65), organising the OWCS (§ 66…70), including selection of the waste collection company (§ 67), incorporation of the waste holders to the OWCS (§ 69) and organising the treatment of the waste classes involved to the OWCS (§ 70), keeping the WHR (§ 71^1), and executing the supervisory (§ 119) [EP, 2004]. Except the enforcement of the legislative acts (WMAP and waste regulation) which is the jurisdiction of the city or parish council, and execution of supervisory, the rest of the waste management duties can be delegated from the local authority to a non-profit organisation which belongs to the local authority or authorities in accordance with the Administrative Co-operation Act. This covers also the drafting of WMAP, waste regulation and OWCS procurement documentation, which relying on the practice of the author, is a service widely outsourced to consulting firms due to the reasons mentioned in the end of this section.

In 2011-2012 the Project "Development of waste management cooperation in Harju County Municipalities" was carried out in Harju County, in which the socio-economical feasibility, benefits, advantages and risks arising from inter-municipal waste management cooperation were analysed and estimated [HOL, 2011]. The Project analysis covered the administrative, social, economic and juridical aspects regarding the reorganisation of the waste management in Harju County municipalities through a waste management cooperation centre. The methodology of the socio-economical cost-benefit analysis, which included financial analysis, and risk and sensibility assessment, is introduced in [Kivimägi and Loigu, 2013] and [Põldnurk 2014].

The cost-benefit analysis was carried out by the Estonian Center 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 waste management situation of the Harju County municipalities and 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 centre (WMC) and implementation of the advanced OWCS [Järve, 2012]. The European Commission's methodology for the cost-benefit analysis of investment projects was used for the analysis [EC, 2008b].

In each of the Harju County municipalities there is at least one public officer who is in charge of the waste management tasks mentioned above. In addition and dependant on the size and administrative structure of particular municipality, more public officers, a head of division, and members of parish government are involved not only to the decision making process but in several cases also to the practical tasks. Usually same public officers are in charge of some other public services as well, since a rural municipality cannot afford hiring a particular specialist to each public service but the services are grouped by general topics (like environmental issues, engineering, social services etc.) and shared between couple of specialists. In Harju County, this makes 23 administrative units which struggle the same problem – multiplicity of the administrative tasks of the officers who cannot specialise on one particular task and therefore cannot develop sufficient competence in all the fields or public services.

In Harju County municipalities only 0.73 work-load is applied on the waste management tasks [Järve, 2012], and the administrative efficiency per capita is 4.4 times lower compared to that of Tallinn City [Põldnurk, 2014]. The administrative structure of the Harju County WMC was designed so, that instead of 23 or more specialists with 0.73 work-loads, only 4 officers were planned to execute same tasks for all 23 municipalities. The employment structure of the WMC followed that of Tallinn City Government Environment Department Waste Management Division taking into account the realistic work load arising from the projected number of waste collection districts and cycle of the OWCS procurements, number of inhabitants and waste holders to be served, existing waste management utilities (public waste stations and collection points), and other tasks such as amendment of legislation and WMAPs of the members.

2.3 Optimisation of waste collection logistics

The OWCS is defined as 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 [EP, 2004, § 66(1)]. The limit of the size of the waste collection district set in the Waste Act is 30,000 inhabitants [EP, 2004, § 67(5)]. The gap between the requirement and reality stands in the fact that there are only 5 cities out of total 215 local authorities in Estonia which number of inhabitants exceeds 30,000 (Tallinn, Tartu, Narva, Pärnu, Kohtla-Järve) [KOP, 2013]. Most of the waste collection districts in Estonia are formed on the basis of the administrative territory, and 70% of municipalities have less than 4,000 inhabitants. Only in few regions the municipalities have cooperated to form conjoined waste collection districts which then comprise a reasonable number of inhabitants.
The current actual market share in Harju County (Fig 1, Table 2) follows the general idea of the projected waste collection districts [Põldnurk, 2014, Fig 1, Table 2] with few exceptions (Loksa, and Maardu towns, Keila parish). However, it may shift in time when the current contracts expire and new procurements will be held. The validity of the current OWC contracts fluctuates within 3 years from 2014 to 2017, and there is no certainty about the distribution of the current market share, as logical or optimal it may seem to be, after expiry of any current contract and proceeding of new procurements.

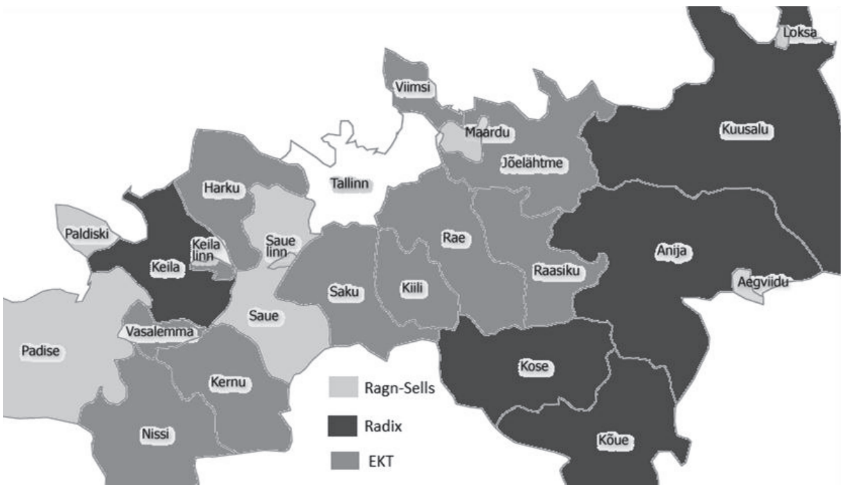

Figure 1. OWCS market share between 3 waste companies

Table 2. The OWCS market share (2014) by inhabitants, territories and waste tonnes (2012)

Actual market share	population	%	territory km^2	%	MMW 200301	%	PC 200101	%	BW 200108	%
EKT	85,832	56.4%	1,569	37.7%	17,478	55.9%	1,542	73.6%	517	50.4%
Ragn-Sells	41,343	27.2%	653	15.7%	9,625	30.8%	422	20.2%	466	45.4%
Radix	24,986	16.4%	1,941	46.6%	4,173	13.3%	130	6.2%	43	4.2%

The transboundary waste collection districts for the Harju WMC were projected on the basis of neighbourhood, and number of inhabitants in order to stay within the limits of Waste Act [Põldnurk, 2014]. The transition period was projected to cover the expiry of all the current OWC contracts. The estimated number of inhabitants, territories, waste generation basing on the 2012 data, and the transition periods in the projected waste collection districts is presented in the Table 3 and Fig 3.

Table 3. Projected waste collection districts, waste tonnes, timing of transition and implementation of the OWCS

Waste collection district	Inhabi-tants	Territory (km^2)	MMW (t) 2012	PC (t) 2012	BW (t) 2012	Period of transition
Keila, Keila town, Kernu, Nissi, Padise, Paldiski town, Vasalemma (I)	28,728	1,095	5,528	210	149	2013-1/8/2016
Harku, Saku, Saue, Saue town (II)	37,659	530	8,886	1,254	498	2013-1/1/2016
Maardu town, Viimsi (III)	33,858	96	8,211	338	123	2013-1/3/2017
Joelahtme, Kiili, Raasiku, Rae (IV)	28,727	677	4,969	189	213	2013-1/1/2014
Aegviidu, Anija, Kose, Kuusalu, Koue, Loksa town (V)	24,005	1,777	3,803	103	43	2013-1/6/2014

In addition to the socio-economical cost-benefit analysis, the financial prognosis and business plan was compiled for three different scenarios (pessimistic, realistic and optimistic dependent on the number of municipalities joining the WMC, and number on inhabitants they comprise). The excel-based model was worked out by UHY Grow LLC accounting company analyst, and the financial prognosis was compiled in cooperation with WasteBrokers LLC experts, including the author. The input data were estimated incomes (waste collection fees, membership fees) and expenditures (investments, loan and interest costs, labour and office costs, costs of the waste management services provided by the WMC). The scenarios based on the numbers of incorporated municipalities and inhabitants. In case of optimistic scenario, all the Harju County municipalities became members of WMC, in case of realistic scenario, some of the municipalities were left out, and in case of pessimistic scenario, some more municipalities were left out. The willingness to join the WMC was estimated by the attitude of the representatives of the municipalities during the project meetings, and in the questionnaires. The financial prognosis projected a balanced budget for three scenarios for five years long period [UHY Grow and WasteBrokers, 2011]. On the Fig 2, the number of incorporated inhabitants in case of different scenarios is presented during the transition period in all the projected waste collection districts.

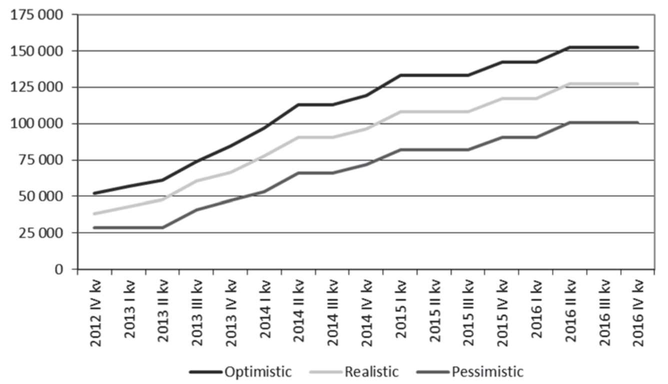

Figure 2. Number of incorporated inhabitants during the transition period

3 Results and Discussion

3.1 Central collection of source separated bio-waste and paper

Arising from the Waste Act (§ 31(2), will be enforced by Jan 1st, 2015) and Waste Framework Directive Art. 11, the local authority shall set up separate collection for at least the following: paper, metal, plastic and glass [EP, 2004 and EC, 2008a]. The source sorting of PC has long-term practice and so it is with packaging waste. But the requirement of separate collection of BW in Harju County municipality bases only on the example of Tallinn City from the year 2007, and is not supported nor demanded by any legislative framework on national or EU level. The only limit value regarding BW is set in the Waste Act § 134(3) according to which from July 2020 the biodegradable fraction in the disposed waste may not exceed 20% by mass. Another restriction set in the Waste Act § 35 is a direct ban to landfill untreated waste [EP, 2004].

The composition of MMW in different types of settlement in Estonia has been analysed in two researches in 2008 and 2013 [Moora, 2008 and Moora, 2013]. Regarding these analysis, the average content of biodegradable fraction (including PC) in the MMW in Estonia was approximately 45% in 2013, and within previous 5 years it had decreased nearly 9%.

Table 4. The percentage of biodegradable fraction in MMW, 2008 and 2013

Biodegradable fraction, % in MMW	2008		2013		Change in %	
	Rapla County	Estonia, avg	Järva County	Estonia, avg	Counties	Estonia
Bio-waste, including:	36,99	36,65	31,10	31,80	-5,89	-4,85
kitchen waste	*32,11*	*30,00*	*27,50*	*26,90*	*-4,61*	*-3,10*
green waste	*3,48*	*5,27*	*2,90*	*3,80*	*-0,58*	*-1,47*
other bio-waste	*1,40*	*1,38*	*0,80*	*1,10*	*-0,60*	*-0,28*
Paper and cardboard	16,27	17,53	12,60	13,50	-3,67	-4,03

According to Moora 2013 the Estonian average MMW consists of 31.8% of BW. Considering the MMW generation in Harju County is 31,397 tonnes, this amount consisted of approximately 10,000 tonnes of BW and total 14,200 tonnes of biodegradable fraction. Only 1,027 tonnes of BW was source sorted and collected separately, and even the potential BW amounts are less than 3,000 tonnes if the separate collection of BW were implemented strictly in all the buildings with more than 10 dwellings in Harju County. The MMW generated in Harju County is, in accordance with the principle of proximity, treated either in Iru CHP incineration plant, Ragn-Sells MBT plant or TJTK's MBT plant, which inter alia treat the biodegradable fraction as well. Thus, there is no legislative pressure for source sorting and central collection of BW in rural areas.
According to the survey carried out by the Estonian Ministry of the Environment amongst Estonian local authorities, most of the local composting facilities are either at the wastewater treatment facilities where sludge is processed with a marginal amount of gardening waste, or facile open windrow composting sites for gardening waste. Technologically equipped composting facilities, where biodegradable kitchen waste can also be processed are only at the regional landfills or few waste stations [EMEDW, 2013]. Today, only manure and sludge from waste water treatment plants with waste from the food industry is really to use for biogas production in Estonia. The quantity of waste from trade, kitchen waste and waste from terraces and gardening has increased year on year, but its energy potential is very small, therefore, the composting process is better [Blonskaja et al., 2014]. The only and nearest suitable composting field for separately collected BW in Harju County is at the TJTK in Jõelähtme parish.

3.1.1 The economical feasibility of source sorted bio-waste collection

The potential volume of source sorting and central collection service of BW n Harju County municipalities is 7,782 m^3/y (1,066 containers · weekly collection frequency 365/7 · size of the container 0.14 m^3). In case of average bulk density of 350 kg/m^3 2,724 (7,782 t · 350/1000) tonnes of BW would be annually collected from Harju county municipalities. This is 2.5 times more than was actually collected in 2012. The calculated potential annual turnover of the BW collection service in case of average collection fee of 1.28 € per 0.14 m^3 container were 70,953 € (1,066 · 365/7 · 1.28 €).
In the Table 5, the potential BW collection rates basing on the number of buildings with 10 or more dwellings, and minimal costs of transportation are presented. Presuming the capacity of an average RCV is 9 tonnes, but since BW cannot be strongly compacted, a mean bulk density of BW in the RCV is considered 0.5 t/m^3 [WRAP, 2009] the calculated fuel costs are as following:

Table 5. BW potential collection rates and transportation costs

	route (km)	Potential BW (t/year)	collection rate (t/route)	number of routes/year	fuel cost (€/year)
Route I, EKT	221	1,421	27.24	316	63,487 €
Route II, Ragn-Sells	176	812	15.58	181	28,917 €
Route III, Radix	123	491	9.41	109	12,202 €

The gate fee of TJTK composting field is 30 €/t [TJTK, 2014] making the treatment cost of the separately collected BW over 82,830 € (30 €/t · 2,274 t). The minimal annual fuel costs (excluding the streets in the villages and towns where the actual collection takes place) on transportation between the collection areas and to the treatment facility (Table 5) in case of fuel price of 1.30 €/L are estimatedly 104,607 €. The minimum labour costs during the transportation are estimated to be around 22,990 € (at an average speed of 60 km/h minimally 1,916 h/year with a salary of 12 €/h taxes included). Thus, the total minimum direct costs of source sorted BW transportation are around 210,427 €/year (82,830 + 104,607 + 22,990). Dividing this number with weekly collection frequency of 1,066 BW containers, it results in 3.79 € as a minimum average collection fee of a 0.14 m^3 BW container, administrative costs yet not included, which is higher than average collection fee for the 0.14 m^3 MMW container in Harju County municipalities – 2.16 €. Thus, economically, the separate collection of BW cannot compete with the collection on MMW. The collection routes for separately collected BW are long, which makes the transportation costs high, the treatment costs are also considerable, thus economical feasibility of central collection of BW questionable.

3.1.2 The environmental feasibility of source sorted bio-waste collection

According to Defra (2005) and IEEP (2010) the CO_2 emissions per litre of diesel burned are 2.6–2.67 kg/L of CO_2 [Defra, 2005; IEEP, 2012]. With the fuel consumption of 0.7 L/km and total 114,952 kilometres per all the collection routes minimal environmental load arising from fuel consumption on the BW transportation only (travelling within the collection areas not included) is around 209 (2.6/1000 · 0.7 L/km · 114,952 km) tonnes of CO_2.

Carbon footprint arising from the different BW treatment operations vary on a large scale. The net CO_2 emissions in case of incineration, home composting and anaerobic digestion are considered negative, respectively -86.7, -88 and -45.8 kg CO_2-eq per tonne of BW, same time the net CO_2 emissions in case of aerobic composting is 32 kg CO_2-eq per tonne of BW. The highest contribution to CO_2 emission has landfilling with 1,188.3 kg CO_2-eq per tonne of BW [EEA].

The potential CO_2 emissions arising from the transportation and aerobic composting of 2,724 tonnes of BW are about 296 (209 + 32/1000 · 2,724 t) tonnes. The outcome of composting process can be used as soil amendment, which somewhat balances the negative environmental impact. If same amount of BW were composted on site, total 536 (296 + 88/1000 · 2,724 t) tonnes of CO_2 emissions would be saved.

Thus, the central collection and aerobic composting of source sorted bio-waste is not environmentally feasible. In the households with gardens and where the MMW collection interval is longer than a week, BW should be composted on site, otherwise the degradation processes launched in the MMW may pose a threat of pollution and smell. Separation of BW from MMW and composting it on site also contributes to the decrease of environmental load arising from MMW transportation.

3.1.3 The economical and environmental feasibility of source sorted paper collection

As to the PC, there are direct targets and requirements set in the EU and local legislation. The Waste Framework Directive Art. 11 (1) requires that by 2015 separate collection shall be set up for at least the following: paper, metal, plastic and glass. The Art. 11 (2a) says *inter alia* that by 2020, recycling of waste materials such as at least paper from households shall be increased to a minimum of overall 50 % by weight [EC, 2008]. Thus, the separate collection of PC is required and should be improved in order to meet these criteria.

According to WRAP (2009) the mean bulk density of mixed paper and cardboard is about 0.112 t/m^3 in a 0.14 m^3 bin and 0.366 0.112 t/m^3 in a rear end loader RCV [WRAP, 2009]. The potential service volume and turnover of central collection of source sorted PC was calculated basing on the actual market share, simplified routes, estimated bulk density and load capacity of the RCV.

Table 6. PC potential collection rates and transportation costs

	route (km)	Potential PC (t/year)	collection rate (t/route)	number of routes/year	fuel cost (€/year)
Route I, EKT	191	2,490	95.51	756	131,396 €
Route II, Ragn-Sells	160	1,299	49.82	394	57,410 €
Route III, Radix	95	449	17.20	136	11,771 €

The economical feasibility of central collection of the source separated PC is limited mostly by the transportation costs and market value of the secondary raw material. The utilisation costs, including costs for preparation for selling like post sorting and packing of PC are considered zero or negative. The average price for baled paper waste has fluctuated in Europe within last 11 years from 87.30 €/t (2009) to 162.90 €/t (2011) being 132 €/t in 2013 [EDCW, 2014]. In Estonia the price for mixed paper waste is 32 €/t [EM, 2014], however, this is not a wholesale but retail price. The direct costs of collection of PC are following: fuel costs 200,576 € (1.3 €/L · 0.7 L/km · 220,414 km), labour costs 44,083 € (220,414 km / 60 km/ h · 12 €/h·), total 244,659 €. The potential income from baled mixed paper waste is minimally 135,600 € (32 €/t · 4,238 t) in Estonia, but if sold to Europe then around 559,350 € (132 €/t · 4,238 t). In the first case the minimal cost per container would be about 3.05 € [(244,659 – 135,600)/ 1,066 / (365/14)] and in the other case the economic profit is considerable, that is 12.20 € [(559,350 – 135,600)/ 1,066 / (365/14)] per container. Presumed, that the waste company prefers to sell the paper waste for higher price, the service can be considered economically feasible.

As to the environmental feasibility of central collection and recycling of PC, it is clear that recycling is the most favourable option compared to home combustion or composting, or landfilling. Being a renewable resource, the organic carbon contained in the wood (original source of paper pulp) is of biogenic origin. In the case of incineration or landfill disposal, the biogenic carbon is released. If the wood is burned, this carbon will be released as CO_2. In the case of recycling and reuse, the biogenic carbon is not released but remains stored in the wood. The resource (forest) savings due to paper recycling increase the uptake of carbon dioxide by the remaining trees and

the carbon is, therefore, sequestered. This amount of carbon (0.55 or 0.83 metric tons of carbon equivalent) is credited to the recycling system that provoked the phenomenon. [Michaud et al., 2010b].
To sum up, the central collection service of source sorted PC can be considered economically and environmentally feasible for two cogent reasons: source sorted PC is a well recyclable secondary raw material which treatment cost is zero or negative, and there is a legislative pressure on PC recycling. In the households where central collection of PC is not applied (less than 10 dwellings in a building), PC should still be source separated and delivered to the public collection containers or waste stations by the waste holders.

3.2 Waste management cooperation and re-municipalisation

Bel, Fageda and Warnerd carried out an empirical analysis which based on studies that compare the costs of public and private production. The results indicated that the more competitive policy environment in the US in comparison to that in other countries reduced the likelihood of finding cost savings with private production. They presumed that the primary benefit from opening up competition for public services was the efficiency improvements this generated among public producers as a result of benchmarking pressure from potential private competition [Bel et al., 2009].
Bel and Mur (2009) analysed the effects of inter-municipal cooperation and privatisation on the delivery costs of urban solid waste services in rural environments. Regarding the two original variables in their work, they found that a greater degree of dispersion within a municipal area affects total costs positively, as the complexity of the service was necessarily increased. At the same time, the "inter-municipal cooperation" variable led to a reduction in costs in municipalities with smaller populations; that was, small municipalities providing the service as an association incurred lower service costs [Bel and Mur, 2009].
Despite fiscal pressures, there are clear signs that municipalities are continuing to move towards re-municipalisation rather than privatisation, in a number of countries in Europe, including Germany, France and the UK. The re-municipalisation has taken place in Germany, UK, France and elsewhere through in-house brought contracts, including inter-municipal incinerators involving factors such as cost of service, control, or contract expiry. Pressure to make cuts still tends to lead to re-municipalisation: half of the municipalities with budget deficits plan some form of restructuring of municipal services, but while 41% of these are considering moving towards inter-municipal cooperation, and 36% towards re-municipalisation, less than 3% are considering privatisation [Hall, 2012].
These analyses support the inter-municipal cooperation model of rural (small) municipalities from three aspects: first, the introduced model maintains the competition though outsourcing the waste collection and treatment services to the private companies; secondly, the cost-savings are expected from the cooperation and re-municipalisation; and thirdly, the administrative efficiency is improved in the municipalities through the cooperation.
Basing on Järve (2012), and Põldnurk (2014), the Harju County municipalities would win both financially, and in administrative efficiency from the inter-municipal cooperation. In addition, also the inhabitants would win financially if the OWCS were organised in conjoined waste collection districts, and in the quality of the public waste management services. Relying on the main results of the socio-economical cost-benefit analysis for the Waste Management Centre of Harju County Municipalities, 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 (Table 7), meaning the municipalities can financially win from the reorganisation of waste management through the cooperation centre.

Table 7. The Investments Profitability Index [Järve, 2012, 6]

Scenarios	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

In case of scenario S1, the benefit 1.2 million euros comes from the labour saving arising from improvement of efficiency, meaning the WMC is capable of executing same amount of waste management tasks with less number of employees. In case of scenario S2 the benefit for local authorities is remarkably bigger (4.7 million euros) because some for the waste management activities presently financed from the municipalities budget will be transferred on the wallets of inhabitants/waste holders (integrated to the OWCS service fee), and same time the income of the municipality doesn't decrease. In this case the municipality wins in all the expenses which accompany the waste management tasks the WMC would take over. Observing the financial profitability of the project from the waste holder's point of view (the expanded FNPV), then the outcome is different because the scenario S2 brings along increased costs (investments, loan interest, V.A.T) while the scenario S1 delivers to the inhabitants the majority of the benefits arising from the implementation of the project with less expenses. However, the expanded FNPV is also positive in case of both scenarios, which is due to the improved administrative and logistical efficiency, and scale effect from inter-municipal cooperation [Järve, 2012; Põldnurk, 2014].

The improvement of waste management services quality arises from the delegation of the waste management duties (except supervisory and legislation enforcement) from the municipality to the WMC, from the improved administrative efficiency and level of competence. The main difference between the two scenarios stand in the cash flow of the waste collection fees. In case of scenario S1, the cash flow remained as in base scenario S0, meaning the municipalities still have to take the costs of public waste management services plus fund the WMC as well, and the waste collection company collects the service fee, including the treatment, in other words, is the owner of the collected waste. In case of scenario S2, the fee is collected by the WMC, who outsources separately the collection and treatment services, and the waste collection company is merely the transporter of waste, which in fact is the original definition of the OWCS in the Waste Act. Thus the WMC gains more control over the OWCS quality, and the cash flow scheme enables to integrate the expenses of some public waste management services (domestic hazardous waste collection, public awareness raising activities, WHR) into OWC service fee. This funding scheme mitigates the lack of finances in the municipalities' budget and is in accordance with the polluter pays principle. The WMC would be practically self-sufficient. According to the expanded FNPV, and expressed in the financial prognosis, the average costs of all the waste management services per capita will decrease compared to the current situation due to the scale effect and improved administrative efficiency.

3.3 Enlarged inter-municipal waste collection districts

As indicated in section 2.2, the contemporary inter-municipal cooperation on waste management field in Estonia comprises altogether approximately 300,000 inhabitants from about 100 municipalities in about 30 inter-municipal waste collection districts. Thus, the average size of a conjoined waste collection district is 10,000 inhabitants, which is still far smaller than eligible. The bigger waste collection districts are obviously more attractive to the tenderers, and motivate to offer lower waste collection fees at the public procurements. The bigger collection districts also enable to optimise the waste collection logistics and thus decrease the environmental impact of the waste transportation.

The solid waste collection logistic costs play a major role in the total solid waste and disposal costs, which approval by many researches. Therefore, solid waste logistic costs model which consider most logistic activities as costs and environmental impact help to improve the solid waste supply chain and minimize the city budget for waste management activities [Rhoma et al., 2010]. According to calculations performed in Shamshiry et al. (2011), about 75% of total solid waste management cost related to waste collection, that is a high proportion of this amount, is related to worker salary and manpower [Shamshiry et al., 2011].

Chu et al. (2013) modelled different waste collection scenarios, and found that in a hypothetical city of 20,000 households the best option to reduce the overall fuel consumption was a weekly food waste collection with alternate weekly collection of the recyclables and residual waste by two-compartment collection vehicles. In general, the fuel consumption for collecting the complete household waste stream decreases when the capture rates for co-mingled recyclables and for food waste increases. Small collection vehicle is ideal for the collection of small amount of waste, such as food waste, at each pick-up point at the low capture rates; while a larger collection vehicle such as the 26-tonne RCV (refuse collection vehicle) is well suited to residual waste collection. The study also showed that the two-compartment RCV is not always fully utilised and is usually limited by the volume of the compartment rather than the vehicle payload during co-collection of household waste. In some cases, the single separate collection of the household waste could consume less fuel than the co-collection by compartmentalised vehicle, when the collection frequency is reduced to fortnightly collections [Chu et al., 2013].

Relying on Nguyen and Wilson (2010) the co-collection and the normal garbage packer RCV consumed approximately 1.8 L and 1.26 L of diesel per km, respectively, while travelling within the collection areas. The average daily fuel consumption was 2—4 times higher on rural routes compared to urban areas. Fuel consumption varied significantly depending on the housing density along the collection route. In addition, approximately 5—6 times as much fuel was required to collect a kilogram of waste on a rural route compared to an urban route.

The collection frequency and capture rates are the key elements of an effective waste collection logistics, however the size of the collection district sets also limits to the logistical optimisation.

Considering an average MMW generation per capita 0.56 kg/day, source sorted PC 0.04 kg/day and source sorted BW 0.02 kg/day in Harju County municipalities (annual waste generation divided to number of inhabitants divided 365 day) [EEIC, 2012; KOP, 2014], it takes minimum 2,300 inhabitants to fill up an 9 tonnes load-bearing capacity RCV weekly with MMW, but at least 32,000 inhabitants in case of PC and 64,000 inhabitants in case of BW. As to the MMW, in areas of dispersed settlement, where distance between the households range from few hundred metres to few kilometres, the refuse collection frequency is often quarterly. Same time the collection district contains also areas of high population density like village centres and small towns with apartment houses where there is need for shorter collection frequency. The PC and BW are separately collected only in towns and village centres from the buildings with 10 or more dwellings.

Figure 3. Projected waste collection districts

It is indicated in the Waste Act that size of the waste collection district should be determined by the estimation that the minimal size of the waste collection district provides the fill-up of the RCV in one collection route [EP, 2004, § 67(5)], in other words, the logistical scheme of the waste collection should be optimal. Therefore, the potential and advantages of the transboundary waste collection districts should be exploited. The inter-municipal cooperation is essential in order to provide a high quality public waste management services unless a municipality comprises at least about 30,000 inhabitants. In addition to the improved logistical efficiency, the enlarged inter-municipal waste collection districts are more attractive to the competition on the OWCS public procurements. The enlarged inter-municipal waste collection districts also equalise the service availability and pricing throughout the region.

Conclusions

Source sorting and separate collection of BW in rural areas is generally not economically nor environmentally feasible. There is no direct pressure arising from legislation on separate collection of BW in rural areas, since the MMW is incinerated, and so is the biodegradable fraction in it. Separate collection of BW can be applied in towns and villages centres with higher population density only if the treatment facility, preferably an anaerobic digester is relatively close, so that the carbon emissions savings arising from the digestion of the BW are not cancelled out by the emissions arising from transportation. The collection service fee in this case should be lower than that of the MMW, so that the holders would be also economically motivated to sort BW. In Estonia, the best treatment option for source sorted BW is composting, but the sparseness of composting fields set geographical limits to the collection areas. In Harju County, were the MMW is incinerated in Iru CHP plant, the best option is not to apply the source separation and central collection of BW in the rural municipalities. Yet in households with gardens, and collection interval longer than a week, BW should be composted on site in order to decrease the costs and emissions of MMW transportation.

Source sorting of PC may be environmentally and economically feasible in towns and village centres of rural areas if the collection routes and frequency are optimised, and collection fee covers the transportation costs. A monthly or fortnightly collection frequency can be applied dependent on what type of containers are used (0.8 m^3 or 2.5 m^3 or bigger). A further logistical study is needed to evaluate the efficiency of co-collection of source sorted PC and MMW. According to the Waste Framework Directive and the Waste Act, the local authorities should set up separate collection of PC from 2015, thus there is a legislative pressure to improve the source sorting of PC.

Inter-municipal cooperation improves the administrative efficiency and level of competence, also the quality public waste management services. The municipalisation of the administrative part of the OWCS may result in financial savings for both the municipalities and waste holders, especially when competition is maintained on the collection and treatment markets by outsourcing these services. The reorganisation of the waste management enables to launch new financial sources by implementation of the polluter pays principle, and mitigate the lack of funds in the municipalities' budgets. The advanced OWCS enables to incorporate some public waste management services costs into MMW collection fee, mitigating the lack of finances in the local authorities' budgets. The administration of OWCS through the WMC improves the availability of the waste collection service and equalises the price levels throughout the region (county).

Inter-municipal waste collection districts improve the waste collection efficiency through added waste amounts and optimised collection routes. Enlarged waste collection districts increase the competition on the public procurement, since new waste collection districts are more attractive to the tenderers. Due to the tighter competition and scale effect, some financial savings are expected as well.

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APPENDIX II CURRICULUM VITAE

Curriculum vitae

1. Personal data

Name	Jana Põldnurk, née Kivimägi
Date and place of birth	29.4.1974
E-mail address	jana.poldnurk@gmail.com

2. Education

Educational institution	Graduation year	Education (field of study/degree)
Eurouniversity	2005	MSc in Natural Sciences/Environmental protection
Eurouniversity	2003	BSc in Natural Sciences/Environmental protection
Tartu Secondary School No.10	1992	secondary education

3. Language competence/skills

Language	Level
Estonian	Native language, fluent
English	Fluent
German	Average
Russian	Basic
French	Basic

4. Special courses

Period	Educational or other organisation
Seminar in Research Writing and Methods, and Dr Richard Felder and Rebecca Brenti workshop on effective teaching, 2011	Tallinn University of Technology
Managing difficult situations with customers, Personnel involvement in local authorities, and Successful negotiations, 2009	Tallinn City Council
The inner climate of organisation and teamwork management, Development interview as motivating leadership practice, and Environmental protection, 2008	Tallinn City Council, Tallinn Environment Department

Quality management training, 2007	Tallinn Environment Department
Environmental impact assessment training, 2005	EMI-ECO LLC
Trainings on public procurements, legislation and performance, 2005	Tallinn City Council, Addenda LLC
From Idea to Fulfilment - International project management, project applications and reporting, 2004	Civitas NPO
Pollution Science Course, 2001	Helsinki University Faculty of Forestry and Agriculture
Laboratory Practical in Inoganic Chemistry, 2001	Helsinki University Faculty of Forestry and Agriculture

5. Professional employment

Period	Organisation	Position
2003-2004	Tallinn Department of Civil Engineering	Specialist
2005-2006	Tallinn Environment department, waste management division	Chief specialist
2005-2009	Eurouniversity	Lecturer
2007-2010	Tallinn Environment department, waste management division	Head of the division
2010-	WasteBroker LLC	Consultant, project manager
2010-	Tallinn University of Technology, Environment Department	Junior researcher, lecturer
2011-2012	Estonian School of Hotel and Tourism Management	Lecturer
2012-	Tallinn University of Technology, Tallinn Law School	Lecturer

6. Research activity, including honours and thesis supervised

6.1 Supervised theses
Eeva-Maarit Nissinen 06/2014, Tallinn University of Technology, Master thesis “The Comparative Analysis of the Municipal Waste Recycling in Germany, United Kingdom and Finland”
Marit Rinaldo 06/2014, Tallinn University of Technology, Master thesis “Implementing Integrated Waste Management Model in Estonia”
Kaarel Keerd 06/2012, Tallinn University of Technology, Master thesis “The Efficiency of Implementing Organised Waste Transport In Nõmme City District”

Maarja Mäesti 06/2012, Tallinn University of Technology, Master thesis „The Environmental Impact of Biodegradable Waste and Source Sorting. The Comparative Analysis of Home Composting and Central Collection in Urban Areas”
Kristiina Jermakova 06/2011, Euroacademy, Master thesis „The comparative analysis of the environmental impact of MSW incineration and disposal“
Jaana Toomik 06/2011, Euroacademy, Bachelor thesis „The environmental impact of organised waste collection scheme. Comparative analysis“
Ervin Tamberg 06/2010, Euroacademy, Master thesis „The Waste Management Action Plan for Mõisaküla City 2010-2015“
Anne-Mari Mägi 06/2008, The Estonian Public Service Academy, Diploma thesis „Instructions for Compiling a Waste Management Action Plan in Local Authorities with Sparse Population Density“
Jaanika Vipper 06/2008, University of Tartu Türi College, Diploma thesis „Composition of the Waste Generated in Health Care Institutions and the Waste Management Order of the Regional Hospital of Estonia“
Merilii Laanepere 06/2008, Tallinna Tehnikakõrgkool/ University of Applied Sciences, Diploma thesis „The Implementation of Central Collection of Biodegradable Waste within Organised Waste Collection Scheme in Tallinn“
Kersti Lehtmaa 06/2006, Eurouniversity, Bachelor thesis „The Environmental Education Programme for Schoolchildren in Rapla County“
6.2 Reviewed theses
Kristjan Tappel 06/2014, Tallinna Tehnikakõrgkool/ University of Applied Sciences, Diploma thesis “Implementing organised waste transport legislation in practice, based on the Harku rural municipality”
Maarja Nigulas 06/2013, Tallinn University „PAYT and It’s Application in Estonia“, Bachelor thesis
Marko Verhovitš 06/2011, Tallinna Tehnikakõrgkool/ University of Applied Sciences, Diploma thesis „The labelling of dangerous waste and the transition to the Globaly Harmonised System“
Hillar Puhk 06/2010, Euroacademy, Bachelor thesis „The Treatment Options for Packaging Waste in Estonia“
Eliko Roomet 06/2009, Eurouniversity, Bachelor thesis „The Recycling Options for the End-of-Life Tyres in Estonia“
Monika Jasson 06/2006, Tallinn University of Technology College of Tõnismäe, Diploma thesis „Implementation of Organised Waste Collection Scheme in Tallinn“
6.3 Research activities on field of waste management, environmental law and energy policy
Participation in the JCI GO Chamber non-profit environmental awareness raising project “ÜKS MÜTS” as the communication manager

Participation in the Union of Harju County Municipalities project „The Development of Waste Managment Cooperation in the Union of Harju County Municipalities“. The project is co-financed by the Ministry of the Financial Affairs of the Republic of Estonia under the programme „Education of the public officials and employees of state and municipalities and non-profit sector“ sub-programme „Development of the organisation“ as the consultant of project manager WasteBrokers LLC
Participation in the Estonian Waste Management Association project „Waste Recycling Cluster“ on behalf of Euroacademy and Institute of the Environmental Technology of TUT
Participation in the INTERREG IV A project of Turku University, Tallinn University of Technology and Tallinn City Government „Sustainable utilization of waste and industrial non-core materials“ on behalf of Tallinn City Government 09/2009-05/2010 and on behalf of Tallinn University of Technology from 05/2010.
Participation in the European Week for Waste Reduction 21-29.11.2009, chief manager on behalf of Tallinn City Government
Member of biowaste cluster on ACR+ (Association of Cities and Regions for Recycling and Sustainable Resource Management) project for waste reduction 2008 on behalf of Tallinn City Government
Participation in the INTERREG III A Helsinki City Government and Tallinn City Government project „Development of the Eco-support Activity” 2006-2008 on behalf of Tallinn City Government
Participation in the INTERREG III B RECO Project 2005-2007 on behalf of Tallinn City Government

APPENDIX III ELULOOKIRJELDUS

Curriculum vitae

1. Isikuandmed

Ees- ja perekonnanimi	Jana Põldnurk, end. Kivimägi
Sünniaeg ja -koht	29.4.1974, Rakvere, Eesti
Kodakondsus	Eesti

2. Kontaktandmed

Aadress	Serva 14, Tallinn 11617, Eesti
Telefon	+372 521 7867
E-posti aadress	jana.poldnurk@gmail.com

3. Hariduskäik

Õppeasutus (nimetus lõpetamise ajal)	Lõpetamise aasta	Haridus (eriala/kraad
Euroülikool	2005	MSc/loodusteadused, keskkonnakaitse
Euroülikool	2003	BSc/loodusteadused, keskkonnakaitse
Tartu 10. Keskkool	1992	keskharidus

4. Keelteoskus

Keel	Tase
Eesti keel	Emakeel, kõrgtase
Inglise keel	Kõrgtase
Saksa keel	Kesktase
Vene keel	Algtase
Prantsuse keel	Algtase

5. Täiendusõpe

Õppimise aeg	Täiendusõppe läbiviija nimetus
Uurimustööde ja artiklite kirjutamise seminar ja Dr Richard Felderi ja dr Rebecca Brenti koolitus „Mõjusa õpetamise õpituba“ inglise keeles, 2011	Tallinna Tehnikaülikool
Praktilised juhtimisvõtted juhi töös, 2010	Tallinna Keskkonnaamet
Rasked situatsioonid teenindamisel: konfliktid, kuulamine kehtestamine, Kaasamiskoolitus	Tallinna Linnakantselei, Tallinna Keskkonnaamet

KOV ametnikele ja Tulemuslikud läbirääkimised, 2009	
Organisatsiooni sisekliima ja ühtse meeskonna toimimine, Vestlus kui tulemuslik ja alluvaid motiveeriv juhtimistehnika ja Keskkonnakaitse koolitus, 2008	Tallinna Linnakantselei, Tallinna Keskkonnaamet
Kvaliteedijuhtimine ja valdkonnapõhised tegevused, Meeskonnatöö ja Ettekannete koostamine, Haldus- ja väärteomenetluse võrdlev käsitlus ja esitamine, 2007	Tallinna Keskkonnaamet, Tallinna Linnakantselei
Haldus- ja väärteomenetluse koolitus ja Riigihangete läbiviimine, uus riigihangete seadus ja Tsüs-i ja Võlaõiguse probleemid praktikas 2005	Tallinna Linnakantselei, Addenda OÜ
Keskkonnamõju hindamine, 2005	EMI-ECO
Ideest teostuseni - rahvusvaheline projektijuhtimine; rahataotluste kirjutamine ja vormistamine, 2004	Civitas MTÜ
Saasteteaduse kursus, 2001	Helsinki Ülikool, Metsanduse ja põllumajanduse teaduskond
Laboratoorne praktikum anorgaanilises keemias, 2001	Helsinki Ülikool, Metsanduse ja põllumajanduse teaduskond

6. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
2003-2004	Tallinna Kommunaalamet	peaspetsialist
2005-2006	Tallinna Keskkonnaamet, Jäätmehoolde osakond	peaspetsialist
2005-2009	Euroakadeemia	lektor
2007-2010	Tallinna Keskkonnaamet, Jäätmehoolde osakond	osakonna juhataja
2010-	Jäätmemaaklerid OÜ	konsultant, projektijuht
2010-	Tallinna Tehnikaülikool, Keskkonnatehnika instituut	lektor, nooremteadur
2011-2012	Eest Hotelli- ja Turismikõrgkool	lektor
2012-	Tallinna Tehnikaülikool, Õiguse instituut	lektor

7. Kaitstud lõputööd

7.1 Lõputööde juhendamine
Eeva-Maarit Nissinen 06/2014, Tallinna Tehnikaülikool „Saksamaal, Suurbritannias ja Soomes tekkinud olmejäätmete taaskasutuse võrdlev analüüs“, magistritöö
Marit Rinaldo 06/2014, Tallinna Tehnikaülikool „Integreeritud jäätmehooldusmudeli rakendamisest Eestis“, magistritöö
Kaarel Keerd 06/2012, Tallinna Tehnikaülikool „Korraldatud jäätmeveo rakendamisest Nõmme linnaosas“, magistritöö
Maarja Mäesti 06/2012, Tallinna Tehnikaülikool „Biolagunevate jäätmete tiheasustusalal kohtsortimise ja kodukompostimise keskkonnamõju võrdlev analüüs“, magistritöö
Kristiina Jermakova 06/2011, Euroakadeemia „Jäätmepõletuse ja ladestamise keskkonnamõju võrdlev analüüs“, magistritöö
Jaana Toomik 06/2011, Euroakadeemia „Korraldatud jäätmeveo rakendamise keskkonnamõju hajaasustusalal ja tiheasustusalal. Võrdlev analüüs“, bakalaureusetöö
Ervin Tamberg 06/2010, Euroakadeemia „Mõisaküla linna jäätmekava 2010-2015“, magistritöö
Anne-Mari Mägi 06/2008, Sisekaitseakadeemia „Jäätmekava koostamine hajaasustusega kohalikus omavalitsuses“, diplomitöö
Jaanika Vipper 06/2008, Tartu Ülikooli Türi Kolledž „Meditsiiniasutustes tekkivate jäätmete koostis ning käitlemise kord Põhja-Eesti Regionaalhaigla Mustamäe korpuse näitel“, diplomitöö
Merilii Laanepere 06/2008, Tallinna Tehnikakõrgkool „Biolagunevate jäätmete tsentraalse kogumissüsteemi rakendamise vajalikkus Tallinnas korraldatud jäätmeveo raames“, diplomitöö
Kersti Lehtmaa 06/2006, Euroülikool „Rapla valla koolilaste keskkonnahariduse programm“, bakalaureusetöö
7.2 Lõputööde retsenseerimine
Kristjan Tappel 06/2014, Tallinna Tehnikakõrgkool „Korraldatud jäätmeveo seadusandluse rakendumine praktikas Harku valla näitel“, diplomitöö
Maarja Nigulas 06/2013, Tallinna Ülikool „PAYT ja selle rakendamine Eestis“, bakalaureusetöö
Marko Verhovitš 06/2011, Tallinna Tehnikakõrgkool „Ohtlike jäätmete veopakenditel kasutatav märgistus ja üleminek ühtlustatud süsteemile Kesti OÜ näitel“, diplomitöö
Hillar Puhk 06/2010, Euroakadeemia „Pakendijäätmete käitlemisvõimalused Eestis“, bakalaureusetöö
Eliko Roomet 06/2009, Euroülikool „Kasutatud rehvide taaskasutamise võimalused Eestis“, bakalaureusetöö
Monika Jasson 06/2006, Tallinna Tehnikaülikooli Tõnismäe Kolledž „Korraldatud jäätmeveo rakendamine Tallinnas“, diplomitöö

8. Teadustöö põhisuunad
   Jäätmehooldus
   Keskkonnaõigus
   Energiapoliitika

9. Uurimisprojektid

SA Keskkonnainvesteeringute Keskuse ja MTÜ JCI GO Koda lastele suunatud keskkonnateavitusprojekti „ÜKS MÜTS“ kommunikatsioonijuht
Osalemine Rahandusministeeriumi meetme „Avalike teenistujate, kohalike omavalitsuste ja mittetulundusühingute töötajate koolitus ja arendamine“ alameetme „Organisatsiooni arendamine“ ja Harjumaa Omavalitsuste Liidu projektis „Jäätmehoolduskoostöö arendamine Harjumaa Omavalitsuste Liidus“
Osalemine Eesti Jäätmekäitlejate Liidu „Taaskasutusklastri“ projektis Euroakadeemia ja TTÜ Keskkonnatehnika instituudi esindajana
Osalemine INTERREG IV A Turu Ülikooli, Tallinna Tehnikaülikooli ja Tallinna linna ühisprojekt „Sustainable utilization of waste and industrial non-core materials” 2009-2013
Euroopa Jäätmetekke Vähendamise Nädal, Tallinna Keskkonnaameti poolne korraldaja 21-29.11.2009
ACR+ (Association of Cities and Regions for Recycling and Sustainable Resource Management) jäätmetekke vähendamise projekti biojäätmete töögrupi liige 2007
Osalemine INTERREG III A Helsingi ja Tallinna ühisprojektis „Ökotugitegevuse arendamine” 2006-2008
Osalemine INTERREG III B RECO projektis (Balti mere riikide jäätmekäitlusalane regionaalne koostöö) 2005-2007

DISSERTATIONS DEFENDED AT TALLINN UNIVERSITY OF TECHNOLOGY ON *CIVIL ENGINEERING*

1. **Heino Mölder**. Cycle of Investigations to Improve the Efficiency and Reliability of Activated Sludge Process in Sewage Treatment Plants. 1992.

2. **Stellian Grabko**. Structure and Properties of Oil-Shale Portland Cement Concrete. 1993.

3. **Kent Arvidsson**. Analysis of Interacting Systems of Shear Walls, Coupled Shear Walls and Frames in Multi-Storey Buildings. 1996.

4. **Andrus Aavik**. Methodical Basis for the Evaluation of Pavement Structural Strength in Estonian Pavement Management System (EPMS). 2003.

5. **Priit Vilba**. Unstiffened Welded Thin-Walled Metal Girder under Uniform Loading. 2003.

6. **Irene Lill.** Evaluation of Labour Management Strategies in Construction. 2004.

7. **Juhan Idnurm**. Discrete Analysis of Cable-Supported Bridges. 2004.

8. **Arvo Iital**. Monitoring of Surface Water Quality in Small Agricultural Watersheds. Methodology and Optimization of monitoring Network. 2005.

9. **Liis Sipelgas**. Application of Satellite Data for Monitoring the Marine Environment. 2006.

10. **Ott Koppel**. Infrastruktuuri arvestus vertikaalselt integreeritud raudtee-ettevõtja korral: hinnakujunduse aspekt (Eesti peamise raudtee-ettevõtja näitel). 2006.

11. **Targo Kalamees**. Hygrothermal Criteria for Design and Simulation of Buildings. 2006.

12. **Raido Puust**. Probabilistic Leak Detection in Pipe Networks Using the SCEM-UA Algorithm. 2007.

13. **Sergei Zub**. Combined Treatment of Sulfate-Rich Molasses Wastewater from Yeast Industry. Technology Optimization. 2007.

14. **Alvina Reihan**. Analysis of Long-Term River Runoff Trends and Climate Change Impact on Water Resources in Estonia. 2008.

15. **Ain Valdmann**. On the Coastal Zone Management of the City of Tallinn under Natural and Anthropogenic Pressure. 2008.

16. **Ira Didenkulova**. Long Wave Dynamics in the Coastal Zone. 2008.

17. **Alvar Toode**. DHW Consumption, Consumption Profiles and Their Influence on Dimensioning of a District Heating Network. 2008.

18. **Annely Kuu**. Biological Diversity of Agricultural Soils in Estonia. 2008.

19. **Andres Tolli**. Hiina konteinerveod läbi Eesti Venemaale ja Hiinasse tagasisaadetavate tühjade konteinerite arvu vähendamise võimalused. 2008.

20. **Heiki Onton**. Investigation of the Causes of Deterioration of Old Reinforced Concrete Constructions and Possibilities of Their Restoration. 2008.

21. **Harri Moora**. Life Cycle Assessment as a Decision Support Tool for System optimisation – the Case of Waste Management in Estonia. 2009.

22. **Andres Kask**. Lithohydrodynamic Processes in the Tallinn Bay Area. 2009.

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25. **Egon Kivi**. Structural Behavior of Cable-Stayed Suspension Bridge Structure. 2009.

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30. **Alar Just**. Structural Fire Design of Timber Frame Assemblies Insulated by Glass Wool and Covered by Gypsum Plasterboards. 2010.

31. **Toomas Liiv**. Experimental Analysis of Boundary Layer Dynamics in Plunging Breaking Wave. 2011.

32. **Martti Kiisa**. Discrete Analysis of Single-Pylon Suspension Bridges. 2011.

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42. **Inga Zaitseva-Pärnaste**. Wave Climate and its Decadal Changes in the Baltic Sea Derived from Visual Observations. 2013.

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45. **Marika Eik**. Orientation of Short Steel Fibers in Cocrete. Measuring and Modelling. 2014.

46. **Maija Viška**. Sediment Transport Patterns Along the Eastern Coasts of the Baltic Sea. 2014.