Journal of Environmental Management 167 (2016) 59–65

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Full cost accounting in the analysis of separated waste collection efficiency: A methodological proposal

Giuseppe D'Onza*, Giulio Greco, Marco Allegrini

Department of Economics and Management, University of Pisa, Italy

ARTICLE INFO

Article history:
Received 30 March 2015
Received in revised form
10 August 2015
Accepted 3 September 2015
Available online xxx

Keywords:
Full cost accounting
Waste collection costs
Standard costs
Variance cost analysis

ABSTRACT

Recycling implies additional costs for separated municipal solid waste (MSW) collection. The aim of the present study is to propose and implement a management tool – the full cost accounting (FCA) method – to calculate the full collection costs of different types of waste. Our analysis aims for a better understanding of the difficulties of putting FCA into practice in the MSW sector. We propose a FCA methodology that uses standard cost and actual quantities to calculate the collection costs of separate and undifferentiated waste. Our methodology allows cost efficiency analysis and benchmarking, overcoming problems related to firm-specific accounting choices, earnings management policies and purchase policies. Our methodology allows benchmarking and variance analysis that can be used to identify the causes of off-standards performance and guide managers to deploy resources more efficiently. Our methodology can be implemented by companies lacking a sophisticated management accounting system.

1. Introduction

Separated waste collection is at the core of the waste management system and represents a key cost driver. Waste collection can generate up to more than 70% of the municipal solid waste (MSW) system costs (Johansson, 2006; Tavares et al., 2009; Greco et al., 2015). Separated waste collection implies additional costs for which the sale of recycled waste often does not compensate. On the other hand, separated waste collection can lower the costs of landfill disposal or incineration (Angelelli and Speranza, 2002; Larsen et al., 2010). Proper estimation and monitoring of the waste collection costs are essential to define the most cost-effective waste collection strategy, increase the efficiency of the waste collection process and avoid excessive tax rates being imposed on the citizens (Fobil et al., 2008; Huang et al., 2011; Jacobsen et al., 2012).

Over the past 20 years, several studies analysed the costs of MSW management in different Countries and proposed a variety of methods and tools to measure the financial performance of the collection, the transportation and the disposal processes (Pires et al., 2011). These methods include the balanced scorecard, integrated waste management scoreboards, aggregate indexes, data enveloped analysis and others (Huang et al., 2011; Mendes et al., 2013). In the U.S., the early experience of the adoption of the full cost accounting (FCA) methods dates to the 1980s. Given the benefits that this method can offer, the U.S. Environmental Protection Agency has promoted the use of FCA since the mid-1990s to support local government's decision-makers with the design of their MSW programs, ensure an effective reporting of costs to citizens and adopt a pay-as-you-throw system (USEPA, 1997).

The U.S. experience shows that municipalities may face several problems upon implementation of the FCA, especially when they adopt cash flow accounting and they figure their expenditures in terms of their current budget (Gupta, 2009). Moreover, the use of different MSW schemes in waste collection and disposal increases the complexity of the waste management operations and the difficulties to track and evaluate the costs. The adoption of a separate waste collection scheme in particular modifies the flow of activities performed to collect, transport, treat and dispose the different types of waste, as well as the resources employed to carry out operations, which results in greater complexity in the measurement of the full cost of WM systems (Karagiannidis et al., 2008). While there is growing awareness of the importance of FCA for measuring the costs of waste collection, transportation and disposal, there is a lack of research on the theoretical and practical implementation of

* Corresponding author. Department of Economics and Management, Via C. Ridolfi 10, Pisa, Italy.
E-mail address: giuseppe.donza@unipi.it (G. D'Onza).

http://dx.doi.org/10.1016/j.jenvman.2015.09.002
0301-4797/

FCA in the waste management sector (Lim, 2011).

This study aims to fill this gap by presenting a procedure for the development of the FCA method, which can be used to measure the full costs of the MSW collection process of different types of waste: paper and paperboard; glass; multi-material (plastic, metal); organic and undifferentiated. We develop the procedure by using data provided by the waste management firms operating in a sample of Italian municipalities.

In this paper, we investigate the Italian setting, characterised by increasing pressure to reach the European Union Waste Directive's long-term objectives in terms of recycling waste (Lombrano, 2009; Passarini et al., 2011). Italian law sets the objectives for separated waste collection each year in accordance with the European Union directive. The target grew from 35% of the total waste collected in 2006 to 65% in 2012. Proper cost monitoring and cost savings are critical for Italian MSW management companies, which struggle with increasing costs and penalties for not reaching separated waste collection targets. This critical role of cost management, as well as the presence of incentives and penalties, makes the Italian context interesting for our research.

The remainder of the paper proceeds as follows: Section 2 introduces the FCA methods; Section 3 describes the procedure used to develop the FCA method to carry out the empirical analysis; Section 4 lays out the empirical findings. Finally, Section 5 includes the conclusions and the practical implications of our study.

2. Theoretical approach

A full cost accounting method is designed to identify all costs, direct and indirect, associated with providing products or services. In the U.S., several local governments are using the full cost accounting method to identify, calculate and report on the total costs of providing MSW management to citizens.

Prior studies analysed the application of FCA in the MSW lifecycle and highlighted several critical issues that emerge when the FCA is put into practice (USEPA, 1997; Gupta, 2009). For example, a key issue is which costs to incorporate in the full cost. The U.S. EPA handbook (1997, p. 6) indicates seven main cost categories: up-front, operating, back-end, remediation, contingent, environmental and social costs. The first three categories cover the entire lifecycle of the MSW activities from the "cradle" (up-front) to the "grave" (back-end) and include: the initial investment for purchasing the necessary equipment to collect and transport waste (up-front costs), the expenses of managing MSW on a daily basis (operating costs) and the expenditures to properly wrap up operations and take proper care of landfills and other MSW facilities at the end of their useful lives (back-end costs). The latter four categories include costs that are not strictly associated with the MSW lifecycle, such as the remediation costs at inactive sites (e.g. landfill) to avoid the contamination of water, land, etc., and the environmental and social costs that include the negative externalities generated by the MSW activities in term of pollution, degradation of the land, etc.

Several studies suggest including the environmental and social costs in the MSW full cost to give the local governments a more comprehensive view of the integrated performance of the MSW management processes using a "triple bottom line": environmental, economic and social results (Bebbington et al., 2001).

Another critical issue regards the allocation process of the indirect costs among the different MSW activities. Management accounting literature suggests four main criteria to identify the proper allocation bases: the cost-and-effect relationship (which is often indicated as the most preferable), the benefits received, the ability to bear and the fairness or equity (Horngren et al., 2013). The identification of the allocation bases inevitably increases in complexity when municipalities use different MSW paths like recycling, composting, land disposal, etc. In these cases, there are several potential allocation bases like the quantity collected, the quantity recycled, the time of performing activities, the number of employees and the cost of labour, to name a few. Consequently, the selection of the most appropriate and reasonable allocation bases for the indirect costs becomes more complex (Debnath and Bose, 2014).

The aim of our study is to propose and implement a management tool to calculate the full collection costs of different types of waste. In this study, FCA is applied to measure the collection costs of four types of waste: paper and paperboard; multi-material (glass, plastic, metal); organic waste and undifferentiated. Our analysis aims for a better understanding of the difficulties of putting full cost accounting (FCA) into practice in the MSW sector and adds to the knowledge of and experience in FCA that may currently be found in the literature.

3. Practical approach

To identify the sample companies, we adopt a stratified sampling process with proportional allocation and take several criteria into account. In total, 68 municipalities were sampled, with populations ranging from about 5000 inhabitants to 900,000 inhabitants. Forty-two waste management companies serve the 68 municipalities. We sent a questionnaire to the sample waste management firms to gather information about the quantity of bins, vehicles and workforce employed in the waste collection process and the cost data. Appendix 1 reproduces an excerpt from the questionnaire. Thanks to support from the National Italian Packaging Association (CONAI), all the sampled companies participated in the research. A one-day field visit was organised at each waste disposal firm to gather further data and request clarification. To check the robustness of the methodology, we carried out the research in 2009 and replicated it in 2011. In this paper, we present the results of the 2011 research.

The measurement of the full cost of the collection activities requires the estimation of direct and indirect costs. As our analysis focuses exclusively on the waste collection process, we took into accounting only the costs associated with the activities included in this process. According to the classification proposed by the U.S. EPA, these costs include: a) *up-front costs*, comprising the initial investment for purchasing the necessary equipment to collect waste, namely bins, vehicles and other types of equipment; b) *operating costs*, including the cost of the workforce, fuel and managing waste collection on a daily basis.

In our study, the direct costs include the bins, vehicles and workforce that are used or involved in the waste collection activities. Usually, once the companies identify the quantity and the unit price, measurement of the direct costs does not present a problem.

Since the initial purpose of the research was to calculate the actual collection costs of different types of waste, we firstly explored the possibility to use the data tracked in the accounting system of MSW management companies.

The analysis of the responses revealed noticeable differences among companies with regard to the purchase price, the maintenance costs and the depreciation rate of the bins and vehicles. Choices like the depreciation rate to be used may depend on earnings management purposes (i.e. the attempt to reduce income taxes), which has nothing to do with operations. Also, the purchase prices may be influenced by choices that are not driven by operational efficiency but by firm-specific or geographical context-specific factors. Some examples are: the frequency of vehicles' breakdowns, which may be related to the quality of road and infrastructure (which is lower in rural areas), the buyer's size and negotiation power with the suppliers and the influence of local governments on the use of local suppliers.

All these factors make the actual cost data less effective in measuring the waste collection costs.

We opted for a mixed approach to calculate the direct cost using standard costs and depreciation rates and actual data about quantities.

The use of standard costs avoids firm-specific accounting choices and purchase policies. In addition, the use of standard depreciation rates avoids older vehicles and high maintenance costs appearing more efficient than the newer vehicles in some firms.

We proceeded as follows:

a) we used a standard cost system to estimate the direct costs for each unit of used bins, vehicles, workforce (purchase price, maintenance costs and depreciation rate for bins and vehicles, labour hour rate for the workforce);
b) we used the actual data for the quantity of bins and vehicles employed in the collection process and the direct labour hours.

In the adoption of a standard cost system, a critical issue is the way in which standards are defined (Drury, 2011). In our analysis, the standards were established as follows:

a) we selected the 10 most efficient companies within our sample basing on to the operating expenses-to-revenue ratio calculated using the company's financial statements;
b) we analysed the data of the best practices relating to the purchase price, the depreciation rate, the maintenance and the cleaning costs for the 11 different types of commonly used bins and the annual cost, including the depreciation rate, maintenance costs, fuel and other operating costs, for nine different types of commonly used vehicles;
c) we then calculated the standard costs as the average costs reported by the best practices companies (reported in the Table 1 for bins and in the Table 2 for vehicles).

With this procedure, we obtained a standard cost for bins, vehicles and workforce, which reflects operational best practice and avoids the differences in, for example, accounting and purchase choices, which may not be driven by non-operational factors.

Table 1 reports the standard costs for bins (depreciation rates are rounded off). Based on the responses of the surveyed companies, the maintenance cost is estimated to be the 5% of the purchase cost each year. We estimated the cleaning cost for bins used for organic and undifferentiated waste. The companies indicated the hourly cost of the cleaning machine (about 47 euros), and the hourly costs of the workforce (standard costs from the national job contracts) divided by the number of bins cleaned per hour. On average, the sample firms indicated four cleanings per year. Thus, we estimated a cleaning cost of 35.6 euros per year for a bin of between 3200 L and 3400 L.

Regarding the vehicles used to collect waste, we asked companies about the purchase price, depreciation rate, and other operating costs such as maintenance, fuel, insurances and taxes. We calculated the standard cost per hour, which is the sum of all operating costs divided by the total number of annual hours of usage.

To determine the standard cost for the workforce, we took into account the salary levels defined by the national law (Table 3). The national job law establishes five salary levels. We divided the annual salary by the total hours worked per year to obtain the workforce cost per hour.

To calculate the cost of the bins, we took into consideration the following variables: quantity, type, purchase price, depreciation rate, maintenance cost, and cleaning cost. As abovementioned, we used the actual data for quantities and types (Appendix 1 reports the table for bins used by the sample companies). The quantity and types depend on the collection process adopted, as well as the key characteristics of the population and the geographical areas served (Bel and Fageda, 2010).

The following equation yields the cost for the bins:

$$\begin{aligned}\text{Bins cost} = {} & Q_1 \times P_1 \times D_1 \times M_1 \times C_1 + Q_2 \times P_2 \times D_2 \times M_2 \times C_2 \\ & + Q_3 \times P_3 \times D_3 \times M_3 \times C_3 + (\ldots) + Q_n \times P_n \times D_n \\ & \times M_n \times C_n\end{aligned}$$

where:

- Q_1, Q_2, Q_3, (…), Q_n is the actual quantity (Q) of the bin type: 1,2, (…) n;
- P_1, P_2, P_3 (…) P_n is the standard purchase price (P) of the bin type: 1,2, (…) n;
- D_1, D_2, D_3 … D_n is the standard depreciation rate (D) for the bin type: 1,2, (…) n;
- M_1, M_2, M_3 … M_n is the standard maintenance cost (M) for the bin type: 1,2, (…) n;

Table 1
Bins standard costs (in euros).

Bins/bags/containers	Purchase cost	Depreciation rates	Annual cost	Maintenance	Cleaning	Total operating cost
Garbage bags	0.05	100%	0.05	–	–	0.05
Bin (less than 20 L)	1.50	20%	0.30	–	–	0.30
Bin (from 20 to 39 L)	4.23	20%	0.85	–	–	0.85
Bin (40 L and above)	7.75	20%	1.55	–	–	1.55
Metal or plastic support for the public garbage bags	10.00	12.50%	1.25	–	–	1.25
Wheelie bin from 120 to 360 L	36.00	12.50%	4.50	1.80	31.29	37.59
Bin from 660 to 1100 L	167.00	10.00%	16.70	8.35	46.93	71.98
Bin 1700 L	400.00	10.00%	40.00	20.00	46.93	106.93
Bin from 2000 to 2400 L	625.00	10.00%	62.50	31.25	35.64	129.39
Bin from 3200 to 3400 L	640.00	10.00%	64.00	32.00	35.64	131.64
Street bin with remote-controlled opening	1000.00	10.00%	100.00	50.00	35.64	185.64
Underground bin	380.00	10.00%	38.00	19.00	35.64	92.64
Container	5430.92	10.00%	543.09	271.55	35.64	850.28
Compactor container	2827.00	10.00%	282.70	141.35	–	424.05
Other (please specify)	16,900.00	10.00%	1690.00	845.00	–	2535.00

Table 2
Vehicles standard costs (in euros).

Type of vehicle	Standard cost per hour of usage
Garbage truck with loader up to 3 square meters	4.98
Garbage truck with loader over 3 square meters	7.94
Garbage truck with compactor up to 20 square meters	17.68
Garbage truck with compactor over 20 square meter	25.11
Standard garbage truck with side loader and compactor	29.42
Truck for container	31.01
Truck for container with crane	31.01
Vehicle specific for underground bins	43.16

Table 3
Standard workforce cost per hour (in euros).

Employee salary level	Workforce cost per hour
1st level	21.72
2nd level	23.52
3rd level	25.38
4th level	27.12
5th level	29.54

- C_1, C_2, C_3 … C_n is the standard cleaning cost (C) for the bin type: 1,2, (…) n.

With regard to the vehicles used in the collection process, we used three variables: quantity, type, and usage cost. The costs are obtained by multiplying the standard cost per hour of usage with the number of usage hours. Appendix 1 reports the types of vehicles that the sample municipalities used.

The following equation yields the cost for the vehicles:

$$\text{Vehicles cost} = Q_1 \times C_1 + Q_2 \times C_2 + Q_3 \times C_3 + (\ldots) + Q_n \times C_n$$

where:

- Q_1, Q_2, Q_3, (…), Q_n is the actual quantity (Q) of the vehicle types 1,2,3, (…), n;
- C_1, C_2, C_3, (…), C_n is the yearly standard usage cost of the vehicle types 1,2,3, (…), n.

We calculated the workforce cost by taking into account the salary level and the number of hours. For each salary level, the salary per hour is calculated. The salary per hour was then multiplied by the number of work hours. Appendix 1 reports the data obtained from the firms through the questionnaire.

The indirect costs considered are: administrative costs, commercial costs, other overhead costs, financial expenses and taxes. Appendix 1, in which we reproduce the section of the questionnaire used to gather these data, shows examples of such costs.

Regarding the indirect cost, we asked the sample companies to provide:

- facilities and other administrative costs;
- commercial costs;
- interest expenses;
- taxes.

The indirect costs allocation process required two phases. Firstly, we allocated the costs to the key activities that the firm performs: collection (separated and undifferentiated), street cleaning, disposal, and other services. We calculated the direct costs of each activity performed and the percentage of the single activity direct costs out of the total direct costs (e.g. collection cost represents 30% of the total direct costs). We then applied this percentage to the indirect costs, which were assigned pro rata to the activities.

Secondly, we allocated the indirect collection costs to each type of waste. The allocation was made using the percentage quantity of specific waste collected out of the total amount of waste. Here the assumption is that the administrative, commercial and other overhead unitary costs do not vary across different types of waste. Table 4 summarises the indirect cost allocation process.

4. Empirical results

Table 5 reports the cost data for types of waste.

For each type of waste, we report the full cost per ton, the full cost per inhabitant, and the quantity per inhabitant.

The data show that the undifferentiated waste collection cost is on average 79.34 euros per ton collected. The collection of separated waste has a significantly higher cost. The separated waste collection costs of paper and paperboard are twice the amount of undifferentiated waste collection costs. Glass has a similar full cost per ton, whilst organic has the highest cost: about 182 euros per ton.

The cost per inhabitant depends on the quantity gathered. The undifferentiated waste collection cost per inhabitant is about 22 euros because of the average quantity gathered per inhabitant: about 307 kg. The quantity gathered influences the economy of scale that is achievable. Organic waste and paper and paperboard are the two most gathered kinds of separated waste, at 73.46 kg and 61.74 kg per inhabitant, respectively.

Table 6 shows the t-test for the difference in the means of the separated waste versus undifferentiated waste. The difference in the mean is significant for each type of waste with the highest *t-stat* for the organic waste (9.36 with *p-value* <0.01). The difference in the mean is also significant at the 1% level if we consider the average full cost per ton of all the separated waste compared with the average full cost per ton of the undifferentiated waste.

Fig. 1 shows the average collection costs for all separated waste and the undifferentiated waste per weight of separated waste collection out of the total collection. The graph shows how the average separated waste collection costs per ton decrease as the percentage of separated collection out of the total collection increases. Where separated waste collection represents less than 25% of the total collection, it costs 185.8 euros on average, while it costs 175.5 euros on average when it represents between 25% and 50% of the total. The cost falls to an average of 168.6 euros if separated waste collection represents more than 50%. By contrast, the average undifferentiated waste collection costs increase as the percentage of the collection of separated waste out of the total collection increases. Below 25%, the average undifferentiated waste collection cost is 67.6 euros, whereas above 50% the average cost is 87.1 euros.

Table 4
Indirect costs allocation process.

Phase	Allocation Criterion
1. Allocation to the key activities: collection (separated and undifferentiated) street cleaning, disposal, and other services.	Percentage of the single activity direct costs out of the total costs.
2. Allocation of the collection indirect costs to each type of waste.	Percentage quantity of specific waste collected out of the total amount of waste.

Table 5
Cost data for each type of waste.

		Mean	Dev. St.	Min	Max
Undifferentiated	Full cost per ton (€)	79.34	34.61	38.41	203.46
	Full cost per inhabitant (€)	22.42	11.64	6.8	83.22
	Quantity per inhabitant (kg)	307.54	147.25	93.78	936.96
Paper and paperboard	Full cost per ton (€)	158.03	88.59	26.0	404.43
	Full cost per inhabitant (€)	8.91	5.94	0.96	29.82
	Quantity per inhabitant (kg)	61.74	33.99	11.01	199.66
Glass	Full cost per ton (€)	157.56	126.15	35.67	741.40
	Full cost per inhabitant (€)	4.22	3.56	0.24	15.57
	Quantity per inhabitant (kg)	29.64	17.63	1.95	86.16
Multi-material	Full cost per inhabitant (€)	6.27	4.25	0.36	19.77
(plastic, glass, metal)	Full cost per ton (€)	224.38	158.86	40.81	752.10
	Quantity per inhabitant (kg)	32.06	16.04	1.97	71.32
Organic	Full cost per ton (€)	182.75	83.03	66.92	439.49
	Full cost per inhabitant (€)	13.55	9.84	0.76	46.25
	Quantity per inhabitant (kg)	73.46	34.10	5.24	160.81

Table 6
Average collection costs comparison.

	Average full cost per ton	Separated versus undifferentiated waste collection	*T-test* for the difference in the mean versus undifferentiated
Paper and paperboard	158.0	78.7	6.81***
Glass	157.5	78.2	4.82***
Multi-material	224.4	145.1	7.33***
Organic	182.7	103.4	9.36***
Average separated waste	174.8	95.4	9.53***
Undifferentiated	79.3		

All p-values are two-tailed; *** Coefficient is significant at the 0.01 level (two-tailed).

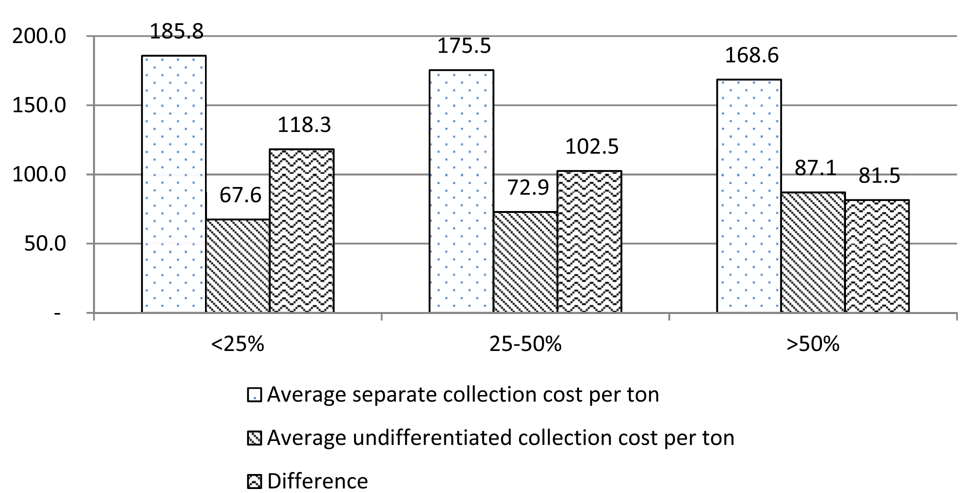

Fig. 1. Average collection cost per ton per weight of separate collection on total collection.

The difference in the collection costs per ton between separated and undifferentiated waste drops some 30%, from 118.3 euros to 81.5 euros. Yet, the average undifferentiated collection cost per ton is still slightly more than half of the average collection cost of separated waste per ton.

5. Discussion and conclusions

In this paper, we develop a full cost methodology and estimate the full collection costs for different types of waste: paper and paperboard; glass; multi-material (glass, plastic, metal); organic;

and undifferentiated. We use the methodology to measure the additional costs of the separated waste collection compared with the undifferentiated waste collection costs.

The method proposed uses a mixed approach that combines the standard cost system with the actual data on the quantity of resources used in the collection process.

This methodology offers several benefits. Firstly, the standards reflect the operational differences but not the differences in the firm-specific accounting choices and purchase policies. The choice of the depreciation rate may depend on, for example, earnings management purposes, such as the attempt to reduce income taxes or increase the remuneration of directors, all factors that have nothing to do with operational efficiency. The use of standard depreciation rates also avoids older vehicles and high maintenance costs appearing more efficient than newer vehicles in other firms. Secondly, our methodology allows companies to implement a cost variance analysis as a control system, investigate the differences between the expected and incurred costs, identify inefficiencies and support business-process improvement activities. The emphasis on variances from standard costs helps to promote a cost consciousness and a culture of efficiency-orientation across the organization. Thirdly, a cost variance analysis supports the development of a management by exception approach. Management does not interfere as long as the standards are adhered to or achieved, and limits its intervention only in cases of variations or when the variations are above a pre-defined tolerance level. Fourthly, in the cost variance analysis, the development of standards using the actual data of the "best practices" companies might offer managers the possibility to evaluate the effectiveness and the efficiency of their collection costs. Such a benchmark is particularly appropriate when the companies belonging to the same industry show a high variation of their up-front and operating costs, as in the cases analysed in this study. Fifthly, the proposed method can also be easily implemented by companies lacking a sophisticated management accounting system.

The implementation of the standard cost method proposed in this study might offer benefits for local authorities to guide the setting of solid waste tariff. Local authorities need to understand the costs of collection, process and disposal MSW for an effective tariff setting. The use of a standard cost system, in which the development of standards is based on the analysis of the "best practices" rather than on the actual costs of MSW companies, avoids the risk that the tariff reflects the operational inefficiencies these companies might present. Moreover, this method enables the local authorities to incentivize the MSW companies to increase their productivity and cover the costs without increasing the waste fees paid by the citizens.

The local authorities might also use standard costs and variance analysis for other purposes. For example, variance analysis might be adopted as a yardstick for the performance evaluation of MSW companies, while standard costs might be used to define the incentive programs for executives in public and private/public partnership MSW companies.

The findings of the analysis carried out in Italy show that the average collection cost per ton of every type of separated waste is significantly higher than the undifferentiated waste average collection cost per ton. The differences for each type of separated waste are all statistically significant. The findings also reveal that the average separated waste collection costs decrease as the percentage of the collection of separated waste out of the total collection increases. By the same token, the average undifferentiated waste collection costs per ton increase as the percentage of the collection of separated waste out of the total collection increases. Increasing the percentage of separated waste collection out of the total collection allows a better exploitation of the collection capacity and achieves cost advantages. As the percentage of the separated waste collection out of the total collection increases, the average undifferentiated waste collection becomes less efficient with an increasing cost per ton.

Despite the 30% reduction in the difference, the undifferentiated waste average collection costs per ton are still about half of the average separated waste collection costs per ton. However, our findings indicate that as the percentage of separated waste collection increases, the separated waste collection may become more efficient and more economically viable.

Our study may suggest that proper separated MSW cost management promotes the responsible use of waste as a resource. Separated waste collection is the basis for the use of waste as an economic resource. The European Commission claims that the economy of recycling has great potential in terms of wealth and job creation (European Commission, 2011). Recycling and reuse can also make a substantial contribution to social and environmental sustainability. The recycling of waste reduces the consumption of natural resources and is beneficial to public health and safety, because it limits the usage of polluting waste disposal methods, such as landfills and incinerators.

This study acknowledges some limitations. To assess the economic convenience of recycling versus undifferentiated waste, the waste lifecycle needs be studied in its entirety. Future research could investigate the costs of the full waste lifecycle, including the revenues for separated and undifferentiated waste. For separated waste collection, revenues from the sale of recycled waste could be deducted from the collection costs; for undifferentiated waste collection, disposal costs in landfill and incinerators could be added to the collections costs.

Another limitation of our study is that the external cost (e.g. the cost for landfill restoration) is not considered, nor are the general environmental and social costs. Future research might include also these costs in the FCA to provide a more comprehensive assessment of the economic, social and environmental performance of the waste collection processes. Finally, this study uses a single allocation basis for allocating the indirect costs to the types of waste. This choice might distort the cost measurement when the overheads are a greater portion of the total cost of business operation. Future studies could help to identify alternative methods like the use of activity-based cost systems that MSW management companies might use to increase the accuracy of cost measurement. However, companies can easily implement our approach without a sophisticated management accounting systems, whereas the activity-based cost systems are costly and complicated to implement.

Acknowledgements

The Authors would like to thank the CONAI for the financial support and the municipalities which participate to the study. We thank the participants in the 2012 CONAI conference and Dr. Claudio Del Lungo for their helpful comments.

Appendix 1. Extract from the questionnaire used in the research

The sections below were repeated for each type of waste: paper and paperboard; glass; multi-material (glass, plastic, metal); organic; undifferentiated.

Bins/bags/containers

Bins/bags/containers	Number of units			Notes
	Home collection	Waste deposit point	Total units	
Garbage bags				
Bin (less than 20 L)				
Bin (from 20 to 39 L)				
Bin (40 L and above)				
Metal or plastic support for the public garbage bags				
Wheelie bin from 120 to 360 L				
Bin from 660 to 1100 L				
Bin 1700 L				
Bin from 2000 to 2400 L				
Bin from 3200 to 3400 L				
Street bin with remote-controlled opening				
Underground bin				
Container				
Compactor container				
Other (please specify)				

References

Angelelli, E., Speranza, M.G., 2002. The application of a vehicle routing model to a waste-collection problem: two case studies. J. Operational Res. Soc. 53, 944–952.

Bebbington, J., Gray, R., Hibbitt, C., Kirk, E., 2001. Full Cost Accounting: an Agenda for Action. ACCA Research Report No. 73. Certified Accountants Educational Trust, London.

Bel, G., Fageda, X., 2010. Empirical analysis of solid management waste costs: some evidence from Galicia, Spain. Res. Conservation Recycl. 54 (3), 187–193.

Debnath, S., Bose, S., 2014. Exploring full cost accounting approach to evaluate cost of MSW services in India. Res. Conservation Recycl. 83, 87–95.

Drury, C., 2011. Cost and management accounting. An Introduction, seventh ed. Cengage Learning EMEA, Andover.

European Commission, Directive 2011/65/EU on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment, 2011, http://www.epeat.net/documents/EPEATreferences/EURoHSDirective.pdf, (March, 3, 2015)

Fobil, J.N., Armah, N.A., Hogarh, J.N., Carboo, D., 2008. The influence of institutions and organizations on urban waste collection systems: an analysis of waste collection system in Accra, Ghana (1985–2000). J. Environ. Manag. 86 (1), 262–271.

Greco, G., Allegrini, A., Del Lungo, C., Gori Savellini, P., Gabellini, P., 2015. Drivers of solid waste collection. Empirical evidence from Italy. J. Clean. Prod. 106, 364–371.

Gupta, K.P., 2009. Cost Management. Measuring, Monitoring and Motivating Performance. Global India Publication Ltd, New Delhi.

Horngren, C.T., Datar, S.H., Rajan, M.D., 2013. Cost Accounting: a Managerial Emphasis, fourteenth ed. Prentice Hall, New York.

Huang, Y.T., Pan, T.C., Kao, J.J., 2011. Performance assessment for municipal solid waste collection in Taiwan. J. Environ. Manag. 92 (4), 1277–1283.

Jacobsen, R., Buysse, J., Gellynck, X., 2012. Cost comparison between private and public collection of residual household waste: multiple case studies in the Flemish region of Belgium. Waste Manag. 33, 3–11.

Johansson, O.M., 2006. The effect of dynamic scheduling and routing in a solid waste management system. Waste Manag. 26, 875–885.

Karagiannidis, A., Xirogiannopoulou, A., Tchobanoglous, G., 2008. Full cost accounting as a tool for the financial assessment of Pay-As-You-Throw schemes: a case study for the Panorama municipality, Greece. Waste Manag. 28, 2801–2808.

Larsen, A.W., Merrild, H., Møller, J., Christensen, T.H., 2010. Waste collection systems for recyclables: an environmental and economic assessment for the municipality of Aarhus (Denmark). Waste Manag. 30, 744–754.

Lim, M., 2011. Full cost accounting in solid waste management: the gap in the literature on newly industrialised countries. Doctoral dissertation. Institute of Certified Management Accountants.

Lombrano, A., 2009. Cost efficiency in the management of solid urban waste. Resources. Conservation Recycl. 53, 601–611.

Mendes, P., Santos, A.C., Nunes, L.M., Teixeira, M.R., 2013. Evaluating municipal solid waste management performance in regions with strong seasonal variability. Ecol. Indic. 30, 170–177.

Passarini, F., Vassura, I., Monti, F., Morselli, L., Villani, B., 2011. Indicators of waste management efficiency related to different territorial conditions. Waste Manag. 31, 785–792.

Pires, A., Martinho, G., Chang, N., 2011. Solid waste management in European countries: a review of systems analysis techniques. J. Environ. Manag. 92 (4), 1033–1050.

Tavares, G., Zsigraiova, Z., Semiao, V., Carvalho, M.D.G., 2009. Optimisation of MSW collection routes for minimum fuel consumption using 3D GIS modelling. Waste Manag. 29, 1176–1185.

United States Environmental Protection Agency (USEPA), 1997. Full Cost Accounting for Municipal Solid Waste Management: a Handbook. http://www.epa.gov (March, 3, 2015).