



“Gheorghe Asachi” Technical University of Iasi, Romania



START-UP OF THE DOOR-TO-DOOR MUNICIPAL SOLID WASTE SEPARATE COLLECTION SERVICE IN A LARGE METROPOLITAN AREA

Sabino De Gisi^{1*}, Francesco Todaro¹, Vincenzo Campanaro², Michele Notarnicola¹

¹*Department of Civil, Environmental, Land, Building Engineering and Chemistry, Polytechnic University of Bari, Via Orabona n. 4, Bari, I-70125, Italy*

²*Environmental Protection Office, Municipality of Bari, Via Marchese di Montrone n. 5, Bari, I-70122, Italy*

Abstract

The study describes the start-up phase of the door-to-door separate collection service of municipal solid waste (MSW) in a large metropolitan area, analysing not only the performance in terms of separately collected waste but also the feedback from citizens on how to improve it. For the scope, the case study of the city of Bari (Southern Italy) was considered. The methodological approach involved primarily the subdivision of the entire municipality into eight homogeneous territorial zones (HTZ) considering population density and space availability. Additionally, each HTZ was decomposed into unitary areas, which in turn were classified according to the degree of feasibility in implementing door-to-door separate collection. During the first year of operation, results showed excellent performance in terms of separately collected waste (>80%) highlighting the goodness of the adopted technical approach as well as the convenience in acquiring feedback from users during the start-up of the service. While expressing positive satisfaction about the door-to-door system, users consider the adopted sanctioning and control system to be critical. The same was considered insufficient to deal with the well-known phenomenon of “waste tourism”.

Keywords: citizen involvement, door-to-door collection, municipal solid waste, service performance, start-up

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1. Introduction

In Europe today separate collection (SC) of each municipal solid waste (MSW) fraction is considered a prerequisite for promoting high quality recycling and high recycling rates. Article 11(1) of the Directive 2018/251 amending Directive 2008/98/EC on waste sets out the general obligation for SC by requiring Member States to set up SC schemes at least for paper, metals, plastics and glass, and by 1 January 2025, for textiles. Article 11(1) of the same Directive requires European Member States to take measures to promote high quality recycling through SC. Technical literature shows a wide variety of ways to collect

different MSW streams such as bring points, door-to-door, co-mingled door-to-door and civic amenity sites. In general, with the bring points system, citizens have to transport waste from the point of production to the point of collection. With the door-to-door system, it is the operator of the collection service who goes to the individual producer users to collect the separated waste (De Feo et al., 2012). Door-to-door collection ranges from one container to six separate containers/bags (including the container for residual waste) while co-mingled door-to-door involves the harvesting of some fractions in a single container such as metal and plastic. Civic amenity sites are used as additional collection schemes, usually accepting the

* Author to whom all correspondence should be addressed: e-mail: sabino.degisi@poliba.it; Phone: +39 0805963279.





same fractions collected in transport containers. For some countries such as Czech Republic, civic amenity sites are the primary collection system for metals and bio-waste. The EU report “Assessment of separate collection schemes in the 28 capitals of the EU” (EC Directive, 2015) showed that practical implementation of the Waste Framework Directive obligations differs significantly across 28 EU Member States. In complex cities such as those in Table 1 it is possible to have multiple waste collection systems simultaneously. In all, 25 cities operate a door-to-door separate collection system, 9 cities collecting each fraction in a separate bin and 16 cities including co-mingled bins in their door-to-door collection infrastructure. Regarding the yield of the separate collected materials, on average, only 19.7% of generated municipal waste is collected separately in EU-28 capitals; this means that 80.3% of the waste still ends up in the residual waste bin.

Literature focusing on different aspects of waste collection clearly agree on the advantages of SC, even if opinions regarding the optimal design of collection systems differ. De Feo and De Gisi (2010) stressed the importance of the technical infrastructure of the collection system and how important it is to inform and motivate users of the service. Bertanza et al. (2018) pointed out how the percentage of recyclables as well as their quality increases with the door-to-door; the collection costs are higher than alternatives although collection rates and consequently revenues are usually higher with a

consequent reduction in waste rates and treatment costs. Giacetti et al. (2009) highlighted that the bring points system encourages inhabitants to produce waste with a higher percentage of impurities. However, it was a reasonable solution for some fractions such as the glass.

Co-mingled collection of recyclables (e.g. plastics and metals) is a widespread practice that tends to reduce costs; however, mixing multiple streams can result in a higher incidence of cross contamination, and the quality of recyclables tends to be lower and rejection rates higher. Furthermore, Giacetti et al. (2009) highlighted how a system based on the SC of organics generates an increase in the dry collection fraction. With reference to the case study of a Greek city (Xanthi, Thrace) undergoing a change in its waste collection system from the existing kerbside to a door-to-door SC system, Tsalis et al. (2018) showed how the most of the respondents were willing to participate in a future door-to-door recyclables collection programme; the factors that influenced the respondents’ attitude with regard to such a programme were associated with level of education, their beliefs about the effectiveness of the current recycling system and also their attitudes towards recycling issues in general. Age and religion significantly affected recycling frequency. Haupt et al. (2018) pointed out how a higher percentage of waste collection did not always imply greater economic and environmental benefits.

Table 1. MSW separate collection schemes for 28 EU-Capitals (EC Directive, 2008)

City	Applied collection schemes				% separate collection considering all systems
	Door-to-door separate 	Door-to-door co-mingled 	Bring points 	Civic amenity sites 	
Amsterdam	x		x	x	12.4
Athens	x	x	x		16.1
Berlin	x	x	x	x	27.4
Bratislava			x	x	14.2
Bucharest			x		2.9
Budapest	x	x	x		7.6
Brussels	x	x	x	x	20.9
Copenhagen	x		x	x	23.7
Dublin	x	x	x		36.6
Helsinki	x		x	x	38.6
Lisbon	x		x	x	11.5
Ljubljana	x	x	x	x	55.4
London	x	x	x	x	25.4
Luxemburg	x	x	x	x	28.4
Madrid	x	x	x	x	11.6
Nicosia	x	x	x	x	6.1
Paris	x	x	x	x	11.6
Prague			x	x	14.3
Riga	x		x	x	18.3
Rome	x	x	x	x	16.3
Sofia	x	x	x	x	4.0
Stockholm	x		x	x	21.5
Tallinn	x	x	x	x	47.2
Valletta	x	x	x	x	7.9
Vienna	x		x	x	29.2
Vilnius	x		x	x	5.5
Warsaw	x	x			4.5
Zagreb	x		x	x	1.0
Average			-		19.7

The optimal value of the collection rate was site-specific and would be determined by both economic and environmental analysis (e.g., based on the Life Cycle Assessment), as reported in De Feo and Malvano (2012). The literature review showed limited information on the methodological approaches to be adopted to monitor the effectiveness of a waste collection service. The latter must also take into account both the technical and social component of the issue addressed. Referring only to the case of a collection system already in operation, Calabrò and Komilis (2019) proposed a semi-qualitative inspection method to evaluate both the door-to-door SC system and the conventional curbside system. The method was based on the combined evaluation of waste collection using a set of indicators and the assessment of the perception of the citizens towards collection and street cleaning services using behavioural questionnaires.

The present paper describes the start-up phase of the door-to-door collection service of municipal solid waste (MSW) in a large metropolitan area, analysing not only the performance in terms of separately collected waste but also the feedback from citizens on how to improve it. The intent was to provide new methodological insights to be applied in similar territorial contexts.

2. Methodological approach

2.1. Experimental plan

The MSW door-to-door SC service was designed and started up in June 2017 in the municipality of Bari (Apulia Region), third city in Southern Italy after Naples and Palermo, characterized by a population in 2017 of 316,656 inhabitants.

The pre-existing collection system described below had lower performances than the Italian Law (LD, 2006), which sets a limit value of 65%. Since the project has to switch to door-to-door, it envisaged the adoption of an innovative methodological approach specially defined by CONAI (Consorzio Nazionale Imballaggi) based on the following main phases: (i) identification of the start-up areas, (ii) start of service for each start-up area and (iii) contextual survey of the start-up area citizen's public perception with the goal of highlighting and resolving any critical issues. The main elements of this developed methodological approach were described below.

2.2. Inlet waste characterization and present mode of waste collection

The inlet MSW consists of compostable material (40 %), recyclable (51.5 %), WEEE (Waste Electrical & Electronic Equipment) and bulky items (2%), sanitary textile such as diapers (1.3 %), hazardous material such as expired pharmaceuticals

(0.2%) and collection residue (5 %).

The major component of the compostable (and in absolute terms) was the organic fraction from food waste (34 %). The main components for recyclables were paper and cardboard (25 %) and plastic (12 %). Such a product composition was in line with that reported in ISPRA (2017) with reference to the period 2008-2017 (Table 2). It was possible to observe how the percentage of paper and cardboard was higher than the Italian average value as already highlighted by De Feo et al. (2017).

Bari has always been a positive anomaly in this regard. The pre-existing MSW collection system was "bring-points" type based on public and collective containers (bins, or other types of containers) where users can deliver the waste (Bertanza et al., 2018). The collection points consisted of a fixed container for undifferentiated residue (mixed waste), a container with wheels for multi-material, a container with wheels for paper, a green bell for glass, a container for used clothing and brown wheeled bins with a lock for organics.

2.3. Methodology for the identification of the door-to-door start-up areas

The design of the door-to-door system involved an in-depth analysis of the territory, its urban and socio-demographic characteristics. First of all, homogeneous areas were identified from the urbanistic point of view on the basis of the analysis of the following variables: population density, type of dwellings, availability of condominium space, availability of space on the sidewalks. Called "Homogeneous Territorial Zones" (HTZ), these areas were delimited by physical, urbanistic or administrative boundaries. The HTZs were then hierarchized according to their vocation for door-to-door collection, starting from the principle that this type of collection can be carried out anywhere but with increasing constraints and penalizing factors depending on the urban context.

Therefore, the HTZs were classified into the following six classes (and colours) (UNI EN, 2017): (i) vocation areas (green); (ii) areas with a predominant vocation (yellow); (iii) areas with penalizing factors (orange); (iv) areas with a poor vocation (red); (v) mixed areas (blue); (vi) agricultural, artisanal and industrial area with low residency level (grey). This led to the creation of a map of the areas with a vocation for door-to-door SC for the municipality of Bari (Fig. 1). Instead, the number of households and inhabitants of each HTZ is shown in Table 3.

It was observed that, excluding the areas classified red and orange (which represent 39.45% of the population with 124,910 inhabitants), the rest of the territory could quickly move to a door-to-door SC, involving 60.55% of the population for a total of 191,756 inhabitants.

Table 2. Characteristics of the investigated inlet MSW

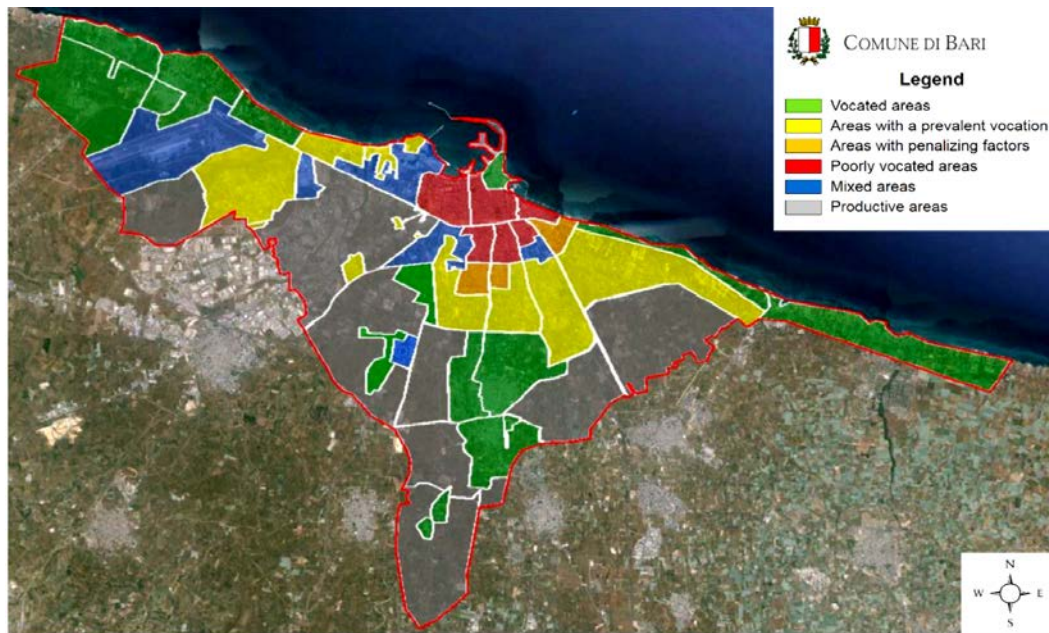
Composition		Unit	Value	
			Our study	Italy (ISPRA, 2017)
Compostable	Organics	% w/w	34.0	35.7
	Cellulosic material	% w/w	6.0	-
Recyclable	Paper and cardboard	% w/w	25.0	22.6
	Plastic	% w/w	12.0	12.8
	Glass	% w/w	7.0	7.6
	Metals	% w/w	2.0	2.6
	Wood	% w/w	2.0	3.0
	Clothing and textiles	% w/w	3.5	3.6
Other	WEEE and bulky items	% w/w	2.0	0.9
	Sanitary textile (diapers)	% w/w	1.3	3.5
	Hazardous	% w/w	0.2	0.3
Residue	Undifferentiated fraction or mixed	% w/w	5.0	7.4

The most suitable areas to switch to door-to-door in the short term were all those with green, yellow, blue and grey colour. Areas with red and orange colours were included among those that had to pass to the door-to-door. Unlike the other areas, these areas would have required “preparatory” mechanisms with the goal of encouraging the separation of waste at family level.

In this regard, while the transition to door-to-door would take place in the most suitable areas, users

of disadvantaged areas (with red and orange colours) would be involved in continuous and widespread communication campaign aimed at increasing the knowledge and awareness of citizens for the proper separation and delivery of waste.

Subsequently, starting from the map in Fig. 1, the so-called “Start-up Zones” of the MSW door-to-door SC service were identified (see paragraph 3.1), representing the areas of the municipality of Bari interested in the launch of the service.

**Fig. 1.** Homogeneous Territorial Zones (HTZ) of the municipality of Bari relating to the vocation to the door-to-door SC scheme**Table 3.** Number of households and inhabitants for each HTZ

Homogeneous Territorial Zones	Colour	Household users	Population	
			Inhabitants	%
Vocated areas	Green	29,351	77,632	24.52
Areas with a prevalent vocation	Yellow	42,359	113,143	35.73
Areas with penalizing factors	Orange	11,065	27,123	8.56
Poorly vocated areas	Red	41,423	97,787	30.88
Mixed areas	Blue	110	288	0.09
Agricultural, artisanal and industrial area with low residency level (productive areas)	Grey	256	683	0.22
Total	-	124,564	316,656	100.00

2.4. Description of the the door-to-door SC service

The door-to-door system was based on teams of vehicles operating in synergy. Different types of satellite vehicles were provided as visible from Table 4. Lower-capacity vehicles are used in areas with small-sized roads and as such are not directly accessible by larger vehicles. These satellite vehicles only collect the waste and then unload their contents into a larger compacting vehicle; the latter transports the waste to the municipal collection center. Depending on the number and qualification of the operator, 5 teams have been identified, the description of which is given in Table 4. Among the main design parameters of a collection system, a time of 300 min per turn was set for intermediate collection and discharge, plus a time of 60 min for movement between the operational site and the collection area.

For household's users (a total of 124,564), the

door-to-door system also provided for the automatic detection of deliveries by means of RFID tags for all fractions. The collected fractions were as follow: (i) paper and cardboard; (ii) light multi-material (plastic, aluminium and ferrous materials packaging); (iii) glass packaging; (iv) organics; (v) dry residual fraction not differentiable; (vi) sanitary textiles (diapers, only to the users who have requested the service). The collection of used textiles and clothing was unchanged (bring-points) although the availability of specific road containers (anti-intrusion towers), already widespread on the territory, was increased. The selection and attribution of bins to households was based on the average per capita waste productivity and, in the case of apartment buildings, on the number of users per civic number. The colors and characteristics of the bins identified for the various collections were in accordance with the UNI 11686:2017 standards (Table 5).

Table 4. Vehicles and operators used for the door-to-door SC

Typology of team	Team description	Vehicle description	Typology of vehicle
Team A	1 Operator/vehicle driver	Truck with 2.5-3 m ³ tank collection equipment	Satellite
Team B	1 Operator/ vehicle driver + 1 Operator collecting	Truck with simple 5 m ³ tank collection equipment	Satellite
Team C	1 Operator/ vehicle driver + 1 Operator collecting	Trucks with 7 m ³ tank capacity with compactor	Satellite
Team D	1 Vehicle driver + 1 Operator collecting	Truck with double tank collection equipment, with simple tank of 2.5-3 m ³ and compacting tank of 7-8 m ³	Satellite
Team E	1 Vehicle driver + 2 Operators collecting	16/18 m ³ compactor on two axis frame	Main vehicle

Table 5. Collection equipment for household and non-household utilities (Fr = collection frequency)

Collected material	Household			Non household	
	Fr.	Single utility	Multiple utility	Fr.	Utility
Paper and cardboard (joint collection)	1/7	 40 litres	 40 + 360 litres	1/7	 40, 120, 1100 litres
Cardboard (selective collection)	-	-	-	3/7	 in bulk or roll containers
Light multi-material (plastic, steel, tinsplate and aluminium packaging)	1/7	 PE 100 litre bag with alphanumeric code	 PE bag 100, 360 litres	3/7	 80-100 litre bag or 360 litre wheeled bin
Glass	1/14		 40, 240 litres	3/7	 40, 120 litres

Organics (food waste)	3/7	 biodegradable bags, 10 litre holed bin, 20-24 litre closed bin	 biodegradable bags, 10 litre holed bin, 240 litre closed bin	6/7	 120, 240 litres
Undifferentiated waste (also called residue or mixed waste)	2/7	 40 litres	 40, 360 litres	2/7	 40, 120 and 240 litres
Sanitary textiles (diapers)	4/7	 20, 24 litres on request	 20, 24 litres on request	-	-

Single users, i.e. those located in buildings with only one dwelling or up to 8 units per building (for a total of 43,906 single users, 32% of the total), delivered the purpose-separated waste directly on the road, through the relative bin or bag, on days and times fixed by the municipal administration. Apartment buildings users, i.e. those located in buildings with more than 8 residential units (for a total of 93,359 condominium users, 68% of the total), were equipped with kits similar to those of single users, with the exception of the 20-24 liters bin for the organics and without RFID tags. Moreover, apartment buildings users did not need the endowment of self-adhesive labels with a unique identification code for the bags of the multi-material. These users delivered their separate waste to the condominium containers (wheeled bins) located in a private area, with no restrictions on days or hours. Kits distributed for single and multiple domestic users were shown in Table 5. Non-domestic users (a total of 18,905) were treated in the same way as domestic ones. For some wastes, collection occurred simultaneously with that of household users (paper, mixed waste); for others, a specific service was provided with different calendars and frequencies. For non-domestic users, containers equipped with RFID tags were distributed.

Table 5 also showed the frequency of collection. Paper collection was carried out simultaneously for household and non-domestic users. On the other hand, cardboard was collected only for non-domestic users. The frequency of collection of light multi-material was 1/7 and 3/7 for households and non-domestic users, respectively. The remaining frequencies for each fraction and user were shown in Table 5. An element of excellence, automatic waste detection with RFID tags allowed to identify (spatially and temporally) and quantify the single fractions delivered by users.

2.5. Methodology for calculating the percentage of separately collected waste

The calculation of the percentage of separate collection (SC%) of a given area (a zone or the whole

city) was carried out according to the ISPRA-ONR method (ISPRA, 2010), by means of the Eq. (1):

$$SC(\%) = \frac{\sum_i SC_i}{(\sum_i SC_i + UW_{undiff} + B + S_{SC})} \times 100 \quad (1)$$

where:

$\sum_i SC_i$ is the sum of the different collected materials constituting the separate collection, excluding any residues (Table 5);

UW_{undiff} is the sum of the amount of residue (“unsorted municipal waste”, 20.03.01 ERC code) and waste from street cleaning (“waste from street cleaning”, 20.03.03 ERC code);

B is the amount of bulky waste for disposal (“bulky waste”, 20.03.07 ERC code);

S_{SC} is the amount of scraps/residues from separately collected waste sorting facilities.

2.6. Survey to assess the user’s customer satisfaction

Questionnaires were administered to citizens involved in the door-to-door in order to assess the performance of the service and to highlight any critical issues. The questionnaire included a two-part format generally adopted in studies of this type (De Gisi et al., 2017). The first part referred to age, gender, educational qualifications and number of family members. The second part contained 13 questions concerning the public perception of users of the new service of which, the first 12 multiple-responses and the last with free response (Table 6).

The questionnaire was produced in print and digital format. The print format was distributed at the start-up offices where citizens went to collect the annual supply of waste bags. Instead, the digital format was spread online on several websites and social networks supported by the Municipality of Bari, citizens ‘committees, environmentalists, etc.

In total, 305 questionnaires were administered, most of them in digital format (~89%).

Table 6. The submitted questionnaire (English translation and adaptation)

<i>Social aspect</i>	<i>No.</i>	<i>Question</i>	<i>Answers</i>
Personal attributes	-	Age	18-30; 31-40; 41-50; 51-60; 61-70; >70
		Sex	Male, female
		Family members	1, 2, 3, 4, 5, >6
		What is your education level?	First level (primary); Second level (secondary); Third level (high); Fourth level or more (degree, Ph.D.)
		What is your neighbourhood?	Sub-zone 1: S. Spirito; Sub-zone 2: Palese; Sub-zone 3: San Pio, Catino, Palese centro, Palese Macchie; Sub-zone 4: Marconi, San Girolamo, Fesca.
Behaviour	Q1	Why do you think SC is useful?	For environmental protection; for economic savings; other.
	Q2	If you throw away a waste you do not know the classification of, what do you do?	You find out where to dump it; You throw it into the undifferentiated; Other.
	Q3	Have you any difficulty sorting your waste at home?	Yes, the containers take up too much space; Yes, I have doubts about how to sort some waste; Yes, I waste too much time in separating; No; Other.
	Q4	With which type of waste do you have the most difficulty in separating?	Organics; Paper and cardboard; Plastic; Metals; Glass; Used cooking oils; Anybody.
	Q5	What types of waste do you usually separate from the undifferentiated waste?	Organics; Paper and cardboard; Plastic; Metals; Glass; Used cooking oils.
	Q6	Do you think that the current collection frequency for each type of waste is satisfactory?	Yes; No, I believe that the frequency of the organics must be increased; No, I believe that the frequency of plastic and metals must be increased; No, I believe that the frequency of undifferentiated must be increased; No, I believe that the frequency of paper and cardboard must be increased.
Opinion	Q7	Collection methods shown on the information material are clearly exposed?	Yes; No.
	Q8	Do you find the supplied bins suitable for SC?	Yes; No.
	Q9	Do you think that the number of SC bags provided is sufficient for your household's consumption?	Yes; No, I believe that the number of bags for organics should be increased; No, I believe that plastic and metal bags should be increased.
Customer satisfaction	Q10	Are you satisfied by the work done by the collection operators?	Yes; No.
	Q11	Are you satisfied by the work done by road cleaners?	Yes; No; Enough.
	Q12	How do you evaluate the overall door-to-door collection service?	Excellent; Good; Satisfactory; Scarce.
User feedback	Q13	How do you think the door-to-door collection service could be improved?	It is an open question with answers from the user.

3. Results and discussion

3.1. Identification of the door-to-door start-up zones

The map of the Start-up Zones for the city of Bari was shown in Fig. 2. These areas were mainly characterized by comparable populations. The start-up zones were separated by natural boundaries, demarcation barriers and in general “buffer zones”. At the time of their identification, the intention was to

contain the well-known phenomenon of “waste tourism”. As reported De Feo and De Gisi (2010), it represents the passage of (waste) flows between one area and another of the city and in the different phases of the start-up of the new collection system.

The territory of the Municipality of Bari was therefore divided into 8 start-up zones gradually and sequentially involved in the start of the service. The first area was called Start-up Zone 1 (Fig. 3), where the door-to-door SC service has begun in June 2017.

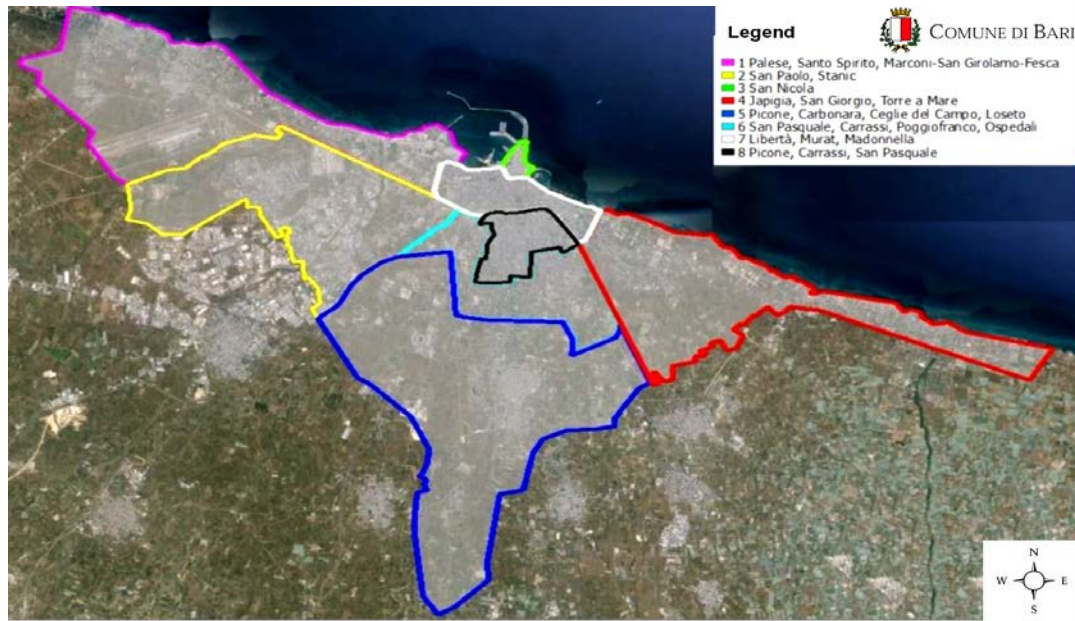


Fig. 2. Start-up zones of the municipality of Bari



Fig. 3. Details of the Start-up zone 1 of the door-to-door SC service

3.2. Service performance in start-up zone 1

The amount of sorted waste collected in the reference year (June 2017 – June 2018) in start-up zone 1 was 8,848 tonnes (Fig. 4a), corresponding to a percentage of separately collected waste of 82.6% (Fig. 4b). Separately collected waste showed a growing trend over time and then stabilised in the last 4 months both for total waste collected separately and for residue. The SC percentage was always higher than the minimum limit of 65% (LD, 2006) (Fig. 4b).

These values were significantly higher than those achieved in the whole municipality of Bari with the previous bring-points system, equal to 36.9% for

the year 2016 (http://ecologia.regione.puglia.it/portal/portale_orp). Mostly collected waste was organics, residue, paper and cardboard, multi-material, glass and lastly diapers (Fig. 4c). The reasons behind the excellent performance of the service were herein described.

3.3. Service evaluation by users

Most of the respondents were women aged between 30 and 50. 48% had a high school diploma and 33% a university degree or higher; therefore, the percentage of those who had a medium-high educational qualification was 81%.

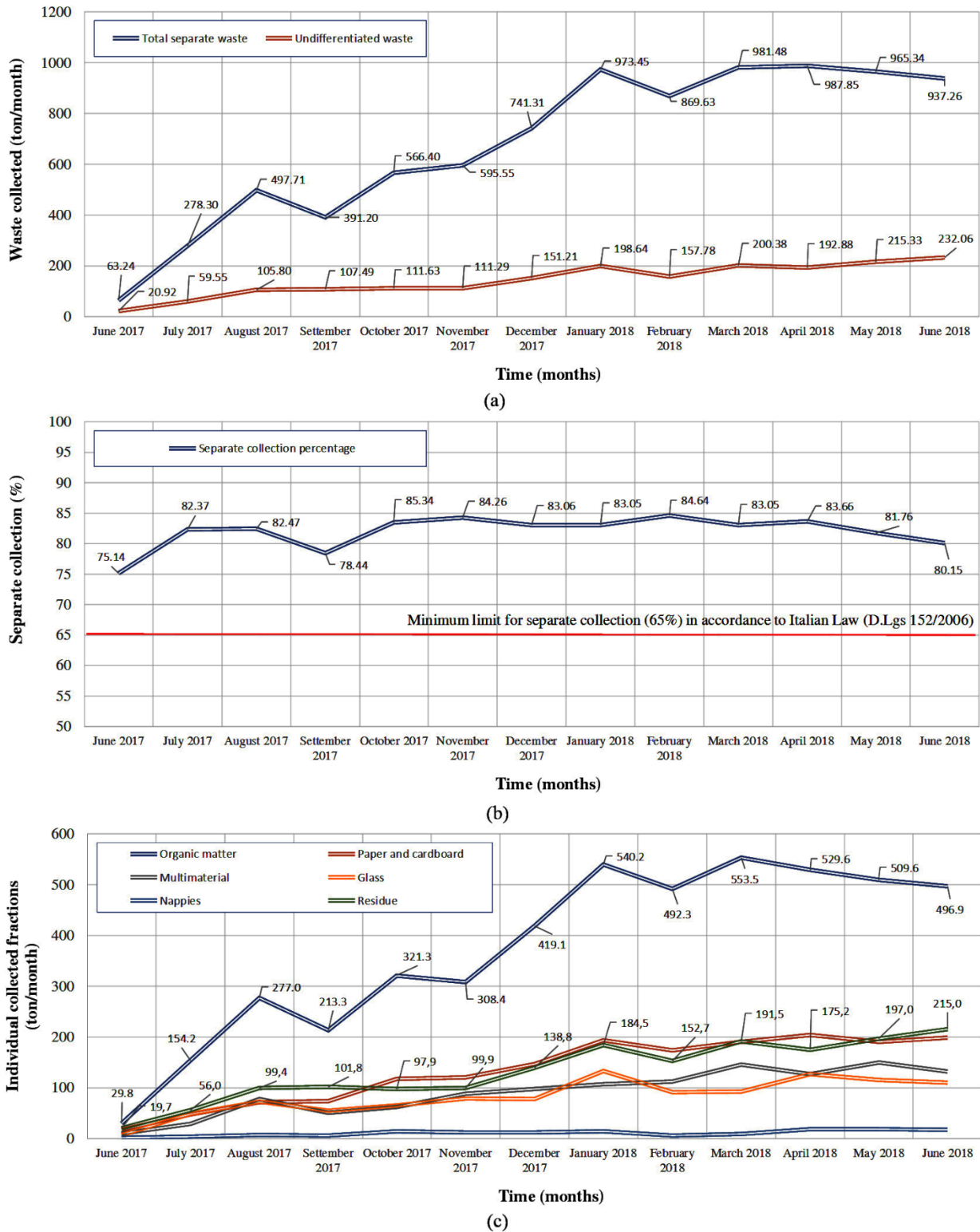


Fig. 4. Door-to-door SC performance for start-up zone 1 in terms of: (a) Amount of collected waste; (b) SC percentage; (c) Amount of collected individual fractions

This sample well represented the population of the start-up zone 1, made up mainly of young families. The typical household was composed of 3-4 members. The results of Fig. 5a allowed to outline the behaviour of the respondents as well as their approach to waste sorting. 92% of respondents were well aware of the importance of SC for the protection of the

environment rather than for economic savings. If they were to dispose of a waste of which they did not know its classification, they were informed of where to dispose of it (68%) (via the Internet, Facebook groups, Junker Apps and information material provided) rather than disposing of it in the undifferentiated bin (28%) (Fig. 5b).

Most of the users of the service did not find it difficult (72%) and a small part (14%) felt that a reason that makes separation complex is the lack of space in the house for the placement of containers (Fig. 5c). This confirmed the positive trend of SC in start-up zone 1 described in the previous paragraph.

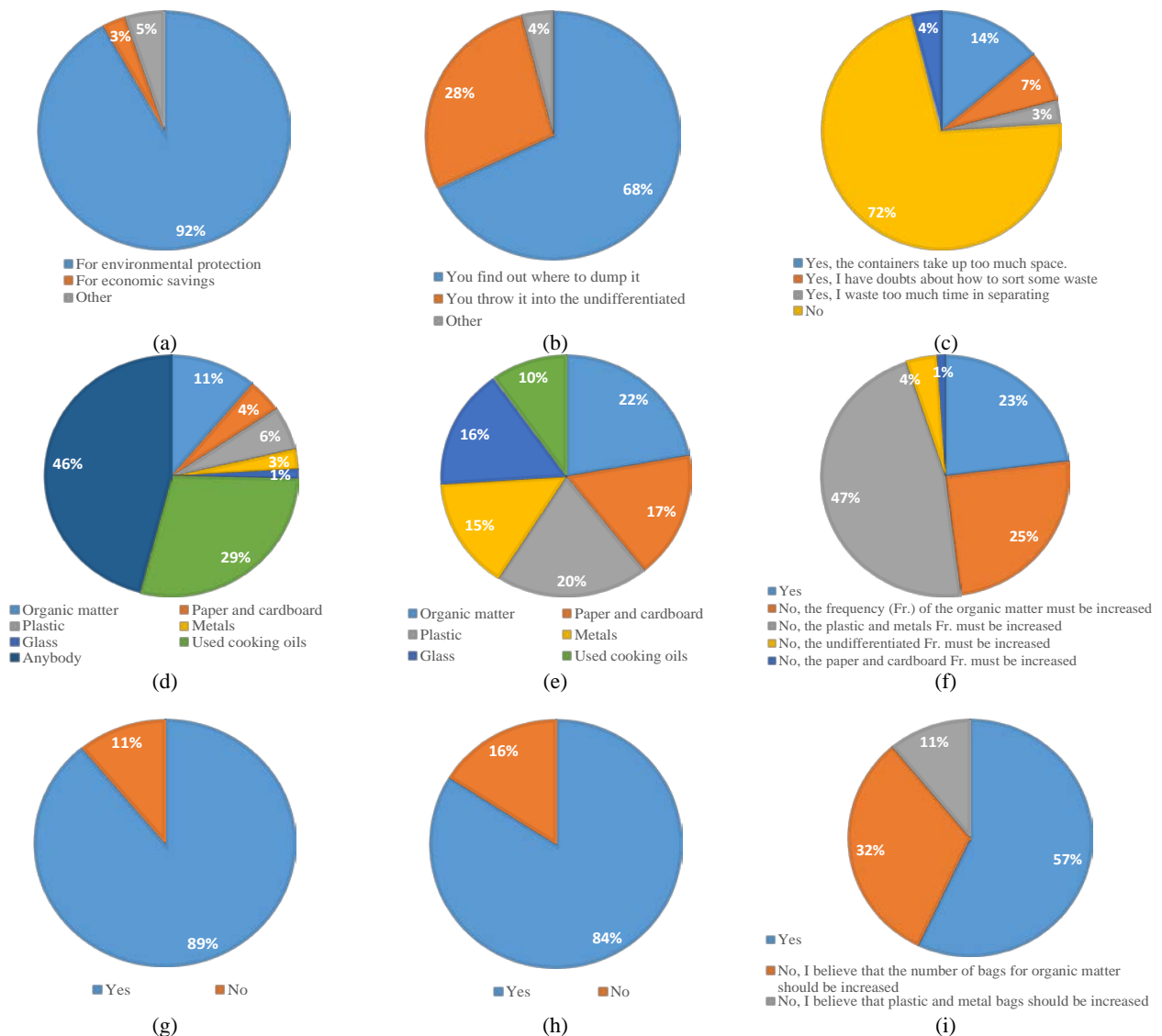
Further confirmation was given by the answers to the Q₄ question “With which type of waste do you have the most difficulty in separating?” where almost half of the respondents (46%) indicated that they had no difficulty with any fraction. On the other hand, the rest found it more difficult to differentiate used cooking oils (28.7%) and organics (11%) (Fig. 5d). Analysing the answers to question Q₅ “What types of waste do you usually separate from the undifferentiated waste?” it was observed that most of the respondents usually separate all the product fractions (Fig. 5e). Subsequently, it was investigated how users evaluated the SC service. The results showed that changes could be made to the collection calendar; for almost half of it (47%), the collection frequency for plastics and metals had to be increased

(Fig. 5f). It was interesting to note that only 4% wanted the frequency of collection of the undifferentiated to be increased. This suggested that the users were already educated to sort waste well.

With regard to the equipment supplied by the Municipality of Bari, a large number of users (89%) considered the collection instructions reported on the information material to be clear (Fig. 5g), and also found the containers supplied to be suitable (84%) (Fig. 5h). As far as bags are concerned, about 57% believed that they were sufficient for their own household, while 32% would have liked to have greater availability (Fig. 5i).

When users were asked to give their opinion on service satisfaction, they expressed a good rate for collection operators (42% answered Yes, 40% answered Enough) (Fig. 5j) and a very bad satisfaction rate for road cleaning operators (70%) (Fig. 5k).

The door-to-door collection service in start-up zone 1 was generally appreciated by users. Only 7% and 21% (in total 28%) of respondents considered the system scarce and satisfactory, respectively (Fig. 5l)



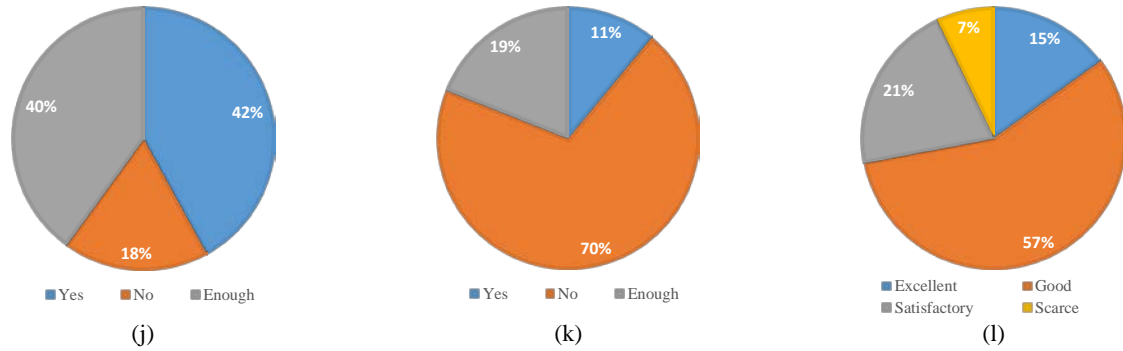


Fig. 5. Results of the sociological survey for the start-up zone 1: (a) Q₁ = Why do you think SC is useful? (b) Q₂ = If you throw away a waste you do not know the classification of, what do you do? (c) Q₃ = Have you any difficulty sorting your waste at home? (d) Q₄ = With which type of waste do you have the most difficulty in separating? (e) Q₅ = What types of waste do you usually separate from the undifferentiated waste? (f) Q₆ = Do you think that the current collection frequency for each type of waste is satisfactory? (g) Q₇ = Collection methods shown on the information material are clearly exposed? (h) Q₈ = Do you find the supplied bins suitable for SC? (i) Q₉ = Do you think that the number of SC bags provided is sufficient for your household's consumption? (j) Q₁₀ = Are you satisfied by the work done by the collection operators? (k) Q₁₁ = Are you satisfied by the work done by road cleaners? (l) Q₁₂ = How do you evaluate the overall door-to-door collection service?

The questionnaire for the evaluation of the door-to-door service along with user feedback were the main source for the identification of the criticalities of the system during the first year of operation. The results (Fig. 6) made it possible to identify the following main criticalities: (i) the need for higher frequency of collection for some waste (19.3%); (ii) the working methods of ecological operators (17.7%); (iii) the need to intensify controls and increase penalties (15.6%). In detail, 47% and 33% of the respondents would have liked the frequency of collection of plastics/metals and of organics to be increased, respectively. Such feedback was also in line with the answers to question Q₆. The second critical point was the bad work by ecological

operators; in particular, 37% of users considered the work of roads cleaners to be insufficient. Again, such feedback was confirmed by the answers to question Q₁₁.

The last critical point concerned the control and sanctioning system put in place by the Municipality of Bari. Users considered inadequate the implemented system of sanctions. This feedback highlighted a criticality already found in the first months of the service's start-up, that was the irregular abandonment of waste either in the countryside or in the bins of nearby neighbourhoods not yet reached by the door-to-door SC service. This was the most damaging aspect of the service, in line with findings already available in the literature (De Feo, 2014).

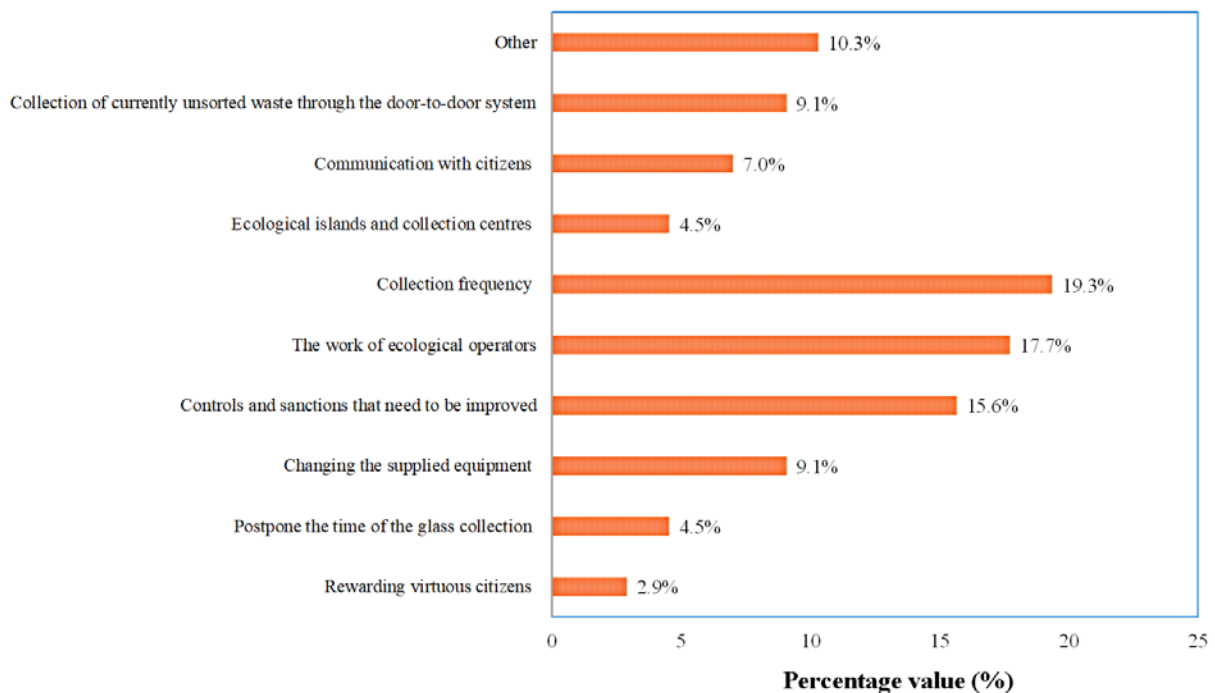


Fig. 6. Criticalities highlighted by the users during the first year of operation (Q₁₃)

4. Conclusions

Based on the obtained results, the following outcomes can be pointed out:

- The heterogeneous nature of a metropolitan area from an urban point of view required careful planning and implementation of the MSW separate collection service, especially in the case of the door-to-door. Among the preliminary steps there was the identification of areas with homogeneous urban characteristics such as population density, type of dwellings, availability of condominium space, availability of space on the sidewalks. The elaboration of a map of the Homogeneous Territorial Zones (HTZ) allowed to classify the areas in terms of vocation to the door-to-door collection; the HTZ map was then used to identify the Start-up Zones together with other criteria such as comparable population distribution as well as respect for the physical/administrative boundaries of the territory.
- Once the door-to-door system was designed in its main variables (e.g. equipment, collection vehicles, personnel), it was advisable to start the system in successive steps, starting from the most vocated areas and providing simultaneous and continuous communication campaigns for those less vocated.
- With reference to the case study of the municipality of Bari (Southern Italy), the excellent performance in terms of waste separately collected (>80%) highlighted the goodness of the adopted technical approach, as well as the convenience in acquiring feedback from users during the starting of the service. While expressing positive satisfaction with the door-to-door system with an overall percentage of 72%, users consider the adopted sanctioning and control system to be critical. The same was considered insufficient to deal with the well-known phenomenon of “waste tourism”.

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