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TERRITORIALITY OF SELECTIVE SOLID WASTE COLLECTION: CASE STUDY IN RIO DE JANEIRO CITY AS SUPPORT TO PUBLIC MANAGEMENT

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ABSTRACT

A territorial analysis of the city of Rio de Janeiro is presented in order to contribute to the planning of selective solid waste collection and decision making in public management of urban cleaning. The applied methodology took into consideration primary and secondary data of the current solid waste collection system in the context of metropolitan geography, crossing this information with the data of road infrastructure, demographics and socioeconomic profile of the municipal population through geoprocessing tools. This information, combined and spatialized, indicated that the use of different modes, depending on the characteristics of each region, can optimize the collection process, reducing operation costs and improving service delivery. These results corroborate the importance of geographic data analysis for the optimization of resources, efficiency and quality of the selective collection programs, in order to comply with the National Solid Waste Policy.

Keywords: Urban planning; Solid waste; Selective collection.

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1. INTRODUCTION

The process of industrialization and technological advances that occurred in the last four centuries resulted in an exponential increase in population and concentration in urban areas, causing serious problems for the environment, including the unbridled generation of solid waste. The generation concentration of these residues is aggravated where the population and consumption concentration are high. The problem of urban waste thus results from the association between the precarious or total lack of adequate infrastructure for cities and the lack of ecological awareness, leading to a picture of chaos (Silva *et al*, 2001).

Financial crisis and the limitation of natural resources associated with environmental and public health damage due to inadequate waste disposal have made society aware of the need for recycling. Thus, the return of recyclable waste to the production chain as a raw material for the production of new products was established by eventual needs, as in times of crisis and scarcity, experienced during the last two great wars (Wells, 1995 apud Periotto; Frulan, 2013).

The first reports on the reuse of the recyclable fraction of waste through the use of sorting plants date from the 19th century (Eigenheer; Ferreira, 2009). However, selective waste collection actually begins in the United States and then arrives in Europe, with the earliest records of selective waste collection and recycling programs dating back to World War II (Santos, 1995 apud Lima; Ribeiro, 2000).

Martins (2002) apud Besen (2006) points out that in developed countries solid waste management went through three specific moments: the first, during the 1970s, focused on the final destination; the second, during the 1980s, in reduction and recycling; and the third, after the 1990s, with the establishment of laws and standards for the implementation of selective collection, recycling and energy use.

In Brazil, with National Policy on Solid Waste (Law No. 12.305/2010), all municipalities of the federation are required to close their dumps and dispose of their non-recyclable waste to landfills. The law also foresees the implementation and progressive expansion of municipal solidary selective collection with the participation of organizations of waste pickers. Joint selective collection is an environmental management tool that should be implemented to recover recyclable material for recycling purposes (Brasil, 2010).

Selective waste collection in Brazil has been the result of informal initiatives and actions by waste pickers organizations. In the country, only 16.66% of the 5,561 municipalities are operating selective collection programs, which correspond to 927 implemented and operating experiences, as shown by research on the theme developed by the Corporate Commitment for Recycling (CEMPRE, 2014).

The National Sanitation Information System (SNIS - *Sistema Nacional de Informações sobre Saneamento*) publishes annually the "Diagnosis of Urban Solid Waste Management", which in its thirteenth edition for 2014, points out that from a total of 3,765 municipalities surveyed, 1,322 reported performing any sort of selective collection, either by Voluntary Delivery Point (PEV - *Ponto de Entrega Voluntária*) or door-to-door. However, there was no assessment of the extent of selective collection in these municipalities, and may only be in one locality, part of the municipality, or throughout the city. Of these 1,322 municipalities, 1,178 said they carry out selective door-to-door collection, serving a total of 52 million inhabitants, a figure well above that of CEMPRE (2014), which indicated 28 million people.

2. BIBLIOGRAPHIC REVIEW

Selective collection: importance and technique

According to Ribeiro and Besen (2011), selective collection plays a fundamental role in the integrated management of solid waste in several ways: it promotes the practice of segregating solid waste directly into the generator for later use, promotes the practice of reducing consumption and waste through environmental education, promotes the socioeconomic inclusion of recyclable waste pickers and provides better organic waste for composting.

For Cunha and Caixeta Filho (2002), the operation of waste collection begins with the vehicle leaving the garage, followed by the displacement to the collection route, covering the entire journey spent to remove waste from collection points, transport to transhipments and/or final destination (sorting plants, landfills, waste picker cooperatives), until return to the point of departure. However, the collection systems deployed are distinct and may range from unorganized systems to systems where material is separated at source into more than 10 types and collected by specialized vehicles. This variation between existing models makes the comparison often complex.

The operating systems generally used are the collection system performed directly on the property and the point of delivery system (Dahlén; Lagerkvist, 2010). For Kogler (2007), the collection system performed directly on the property is one where the material is collected from the individual producer (residences). This service can be divided into two: kerbside system, where each house has one or more containers positioned on the sidewalks, in which the resident is obliged to put the waste for later collection;

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and the full-service system, also known as the door-to-door system, where it is optional for residents to use containers, collectors or bags to dispose of waste, which may be stored inside or outside the home. In the point of delivery system, the resident takes the material produced to specific locations for correct disposal, which can also be divided into two categories: delivery points, which are containers of various sizes located close to homes, with coverage of one post for every 600 inhabitants, as in the case of Aarhus, Denmark (Larsen et al., 2010), or one post for between 400 and 1000 inhabitants, as in the Swedish municipalities (Dahlén et al., 2007). The other delivery system is recycling centers, which are larger areas that can deliver various types of materials, including bulky and hazardous waste, where each center covers approximately 6,000 residents (Larsen et al., 2010).

Kuhn et al. (2018) found, through an integrative systematic review, that most Brazilian municipalities have limitations to comply with the National Policy on Solid Waste, especially for the effective implementation of selective collection.

Conke and Nascimento (2018), analyzing the four main Brazilian surveys on solid waste management, concluded that only 41% of Brazilian municipalities have selective collection, and only 10% of potentially recyclable material is collected.

Grimberg and Blauth (1998) point out that in Brazil there are two basic modalities of selective collection: door-to-door, where cleaning agents and/or environmental agents travel the streets together with the collection vehicle, collecting previously separated recyclables and arranged in front of households and commercial establishments; and PEV, where the population moves to strategically defined locations to dispose of material segregated at home. However, the same authors note that it is difficult to measure community adherence to selective collection through PEV, as well as the risk of vandalism that may present itself, such as the disposal of organic waste and/or dead animals and the damage and destruction of collectors.

As for door-to-door selective collection, although it needs more infrastructure and higher costs for collection and transportation, it provides greater convenience for the population, which results in greater participation by society in the selective collection programs, and enables better control and supervision by the agencies responsible for the execution of the service, allowing specific measures to be taken to ensure greater popular participation (Grimberg; Blauth, 1998).

Bernardo and Lima (2017) state that the key points to be considered when planning the implementation of selective collection, such as frequency, time and form of collection, to avoid inconvenience to the population, are economically viable.

Thus, one of the main bottlenecks for recycling to become efficient is the collection and transportation step of recyclable materials. Due to inadequate planning by the government and the fact that recyclable materials have a high volume in relation to their weight, the collection is often not economically viable. Therefore, the choice of vehicles used for the transport of recyclable materials, storage devices and transshipment areas are crucial for the operation to be economically viable.

In Brazil, several modalities are used to perform selective door-to-door collection, including the truck without compaction (cage or trunk body), compactor truck and wagons (human or motorized traction).

Gil and Avila (2017) analyzed the means used to perform selective collection in Brazil, comparing the compactor truck, box truck and unmanned motor vehicle associated with a transshipment. They found that the unmanned vehicle had lower cost and less impact on local traffic, considering the dimensions of the equipment. However, more structures are needed to cover the same area as a box truck and/or compactor covers. The compacting truck is more efficient, but more costly, and can have significant impacts on traffic, especially on local roads or commercial areas whose roads are narrow, often blocking them while collecting.

The present study discusses the planning of the urban selective collection, based on the territorial analysis and the collection transportation system in the middle of one of the most important cities of the country, Rio de Janeiro, which has a population of approximately 6.2 million inhabitants.

3. MATERIALS AND METHOD

This is a qualitative and quantitative exploratory research, based on pre-existing data and information regarding selective collection in the city of Rio de Janeiro and Brazil, as well as for obtaining new data.

Study area

The municipality of Rio de Janeiro, capital of the state of Rio de Janeiro, is located in the southeastern region of the country (Figure 1) and has the following bordering municipalities: Duque de Caxias, Itaguaí, Seropédica, Mesquita, Nilópolis, Niterói, Nova Iguaçu, and São João do Meriti.

With an area of 1,200,179 km² and approximately 6,453,682 inhabitants, the city has a demographic density of 5,265.82 inhab./km² and a Human Development Index (HDI) of 0.799 (IBGE, 2010), and is subdivided into five Planning

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Areas (PA), 34 administrative regions, and 160 neighborhoods (Rio de Janeiro, 2015).

Solid waste management in Rio de Janeiro/RJ

With respect to solid waste, the regulation of the waste management process is conferred by Municipal Law No. 3,273 of September 6, 2001, which deals with the Management of the Urban Cleaning System in the Municipality of Rio de Janeiro. Article 30 of that law gives the public body or entity the autonomy to “establish and determine the rules and procedures that are necessary to ensure the good operating conditions and quality of services related to the removal of municipal solid waste” (Rio de Janeiro, 2001). In Rio de Janeiro, solid waste management is the responsibility of the Municipal Urban Cleaning Company (Comlurb).

The city’s Municipal Plan for Integrated Solid Waste Management (PMGIRS), prepared following the guidelines of Laws No. 11,450/2007 (which establishes national guidelines for basic sanitation) and No. 12,305/2010 (National Policy on Solid Waste), presents the “diagnosis of the current solid waste situation in the city of Rio de Janeiro in the scenario of 2014”.

According to data from PMGIRS-RJ (Rio de Janeiro, 2015), The average per capita production of municipal solid waste was 1.43 kg, making up about 9,277 tons/day of collected solid waste, and around 8,370 tons were collected from municipal competence. The remaining 907 tons are composed of waste from large generators and civil construction. Of this amount of 8,370 tons of municipally collected waste, 4,900 tons correspond to household waste, representing 58.54% of the total.

Thus, considering only household production, this generation drops to 0.76 kg/inhab./day. Table 1 shows the per capita generation of municipal solid waste by planning area of the municipality, with PA 1, which corresponds to the center of the municipality, the area with the highest generation of waste per capita, with 1.22 kg/inhab./day.

USW: Urban Solid Waste; HSW: Household Solid Waste

Figure 2 shows the composition of household waste in 2014. Of the total 4,900 tons/day of household waste, 41.7% is composed of potentially recyclable materials. However, 25% is effectively recyclable. Of these, 36.9% correspond to paper, 4.0% to metal, 8.4% to glass, and 50.7% to plastic.

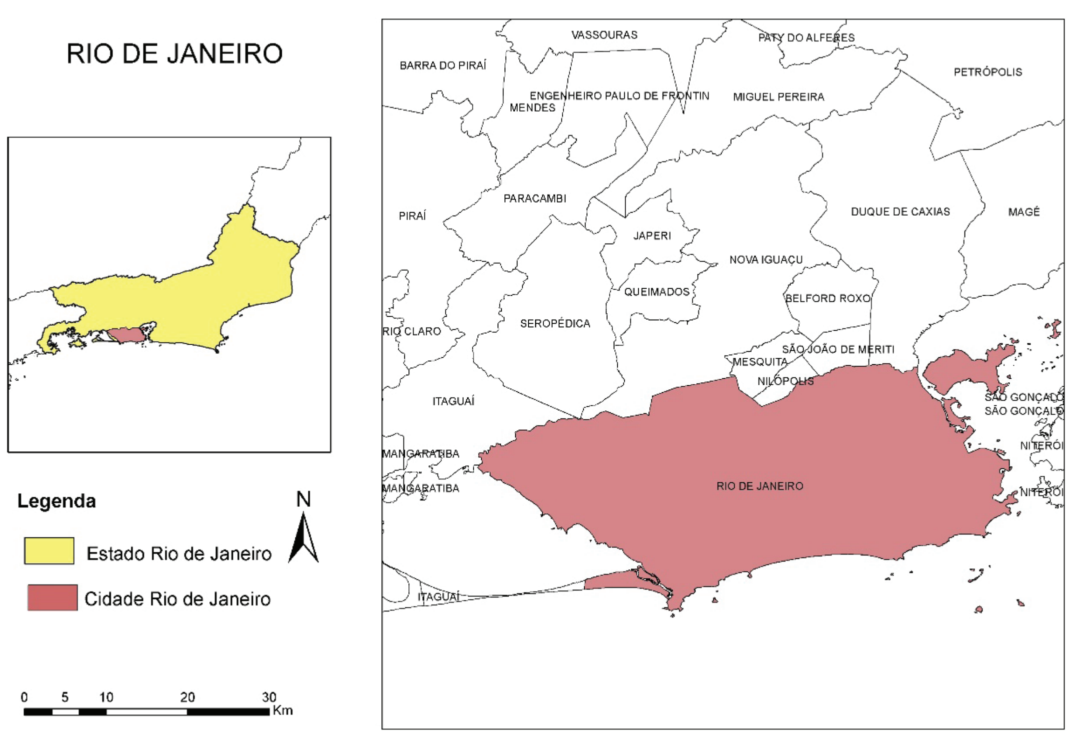

Figure 1. Location of the municipality of Rio de Janeiro/RJ.
Legend: in yellow, Rio de Janeiro State; in red, City of Rio de Janeiro.

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Table 1. Household waste production by Planning Area

Data		PA 1	PA 2	PA 3	PA 4	PA 5	TOTAL
Population	Inhab	307261	1006780	2399437	990545	1749659	6453682
	(%)	4,8	15,6	37,2	15,3	27,1	100,0
Waste Collected	Ton/day USW	707	1338	3379	1388	2415	9227
	Ton/day HSW	375	709	1791	736	1280	4890
	(%)	7,7	14,5	36,6	15,0	26,2	100,0
Per Capita HSW (kg/inhab/day)		1,22	0,70	0,75	0,74	0,73	0,76

Source: Adapted from Municipal Plan of Integrated Solid Waste Management - PMGIRS of the city of Rio de Janeiro (2015).

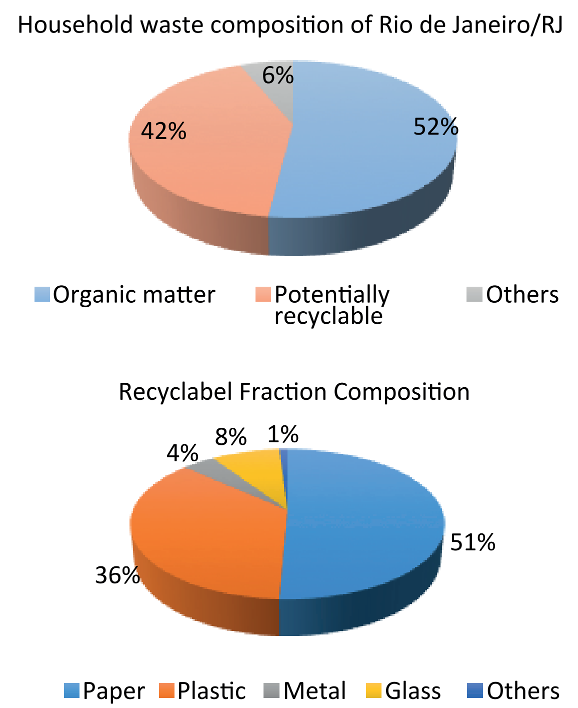

Figure 2. Composition of household waste and its recyclable fraction

Source: Adapted from Municipal Plan for Integrated Solid Waste Management - PMGIRS of the city of Rio de Janeiro, 2014.

In order to meet the Brazilian National Policy on Solid Waste (PNRS - *Política Nacional de Resíduos Sólidos*), with the deactivation of Jardim Gramacho dump in Duque de Caxias/RJ, solid waste generated in the city of Rio de Janeiro is now destined for the Seropédica/RJ Waste Treatment Center, which is managed by CICLUS, and also serves the municipalities of Itaguaí, Seropédica and Mangaratiba.

In order to reduce investment costs, operating costs, traffic impacts and greenhouse gas emissions, given that Seropédica is located approximately 80 kilometers from Rio de Janeiro, the plan foresees the implementation of seven Waste Transfer Stations (WTS), of which five are already implemented (Caju, Jacarepaguá, Marechal Hermes, Santa Cruz and Bangu), pending the Penha and Taquara WTSs.

Figure 3 shows the flow of waste collected in the city of Rio de Janeiro, passing through the WTS and being sent to the Waste Treatment Center (WTC) of Seropédica/RJ.

Selective collection in Rio de Janeiro/RJ

Although started in 1993, shortly after Rio 92, the selective collection of Rio de Janeiro was only boosted from 2010, through a contract signed between the city hall and the National Bank for Economic and Social Development (BNDES) in the amount of R$ 10 million for the implementation of the "Selective Collection Expansion Program in the City of Rio de Janeiro", which aimed at the construction of Screening Plants and the expansion of the vehicle fleet for selective collection..

Although the forecast was to build six Sorting Centers, with total receiving and sorting capacity of 150 tons/day and the generation of 1,500 jobs for municipal waste pickers, only two plants were built, Irajá and Bangu. Due to non-compliance with the goals and deadlines, the contract was terminated and the appeal returned.

The expansion of the fleet occurred in 2012, through the announcement of On-site Auction No. 083/2012, for the hiring of Vehicle Rental and Equipment for Urban Control and Selective Collection. Through this public notice, 13 trucks were quoted and hired with the following specifications: vehicle for collection of recyclables, compactor type 15m^3, chassis 16t, electronic engine and automatic transmission, flatbed compactors and rear loading, with automatic and simultaneous tipping of two plastic containers and 2 wheels/240 liters (Figure 4); and three vehicles for the collection of recyclables, fixed body type 20m^3, equipped with a 3,500 kg x m hydraulic vehicle crane at the moment, and 14,5t chassis.

Currently the collection is performed, even partially, in 113 of the 160 districts of the municipality. Between 2011 and 2015, an average of 12,560 tons per year was collected. Collection is performed using compaction trucks that send the collected material to the two sorting centers and 22 col-

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Figure 3. Flow of waste collected in the city of Rio de Janeiro.

Source: Adapted from Municipal Plan for Integrated Solid Waste Management - PMGIRS of the city of Rio de Janeiro (2015).

Figure 4. Truck used in the selective collection of Rio de Janeiro.

lectors' cooperatives located in the municipality. The vast majority of cooperatives are located in the West Zone of the city, with 13 groups, followed by the North Zone with seven groups and Center, with four cooperatives (Rio de Janeiro, 2015).

The days and times of collection by location are available on the website of the municipality's Secretariat of Environment. It is up to the population not to mix the organic and waste fraction with the recyclable materials, which should be stored in transparent or translucent bags in blue and green colors, so that the collection agent can verify that there are no unwanted materials along with the recyclable material (organic or personal hygiene waste) and put in front of your establishment at the correct time and day.

Territorial analysis

Data were obtained from IBGE (2010), Rio de Janeiro/RJ road network (material provided by the Non-Governmental Organization Institute for Transport & Development Policy – ITDP Brazil) and information from PMGIRS 2014. The software used for the territorial and population analyzes of the city of Rio de Janeiro/RJ was ArcGis 10.1.

The first step in the development of territorial analysis was to define general elements for the construction of a methodology aimed at defining recyclable solid waste collection systems in the city of Rio de Janeiro.

The analysis was thus based on territorial aspects that help to evaluate and define the method of collection for a territory with different socio-environmental characteristics, and the environmental aspects related to the relief, declivity of the slopes that play an important role on urban mobility and, consequently, the road desire implanted on this relief.

Then, the social aspects related to the distribution of the population by neighborhoods were analyzed, considering the total population and the demographic density, since the neighborhoods have variable dimensions, and it is necessary to evaluate both types of relations to understand the population distribution. Associated with this were the average

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household income of the neighborhoods and the total number of roads in kilometers per neighborhood. This correlation makes it possible to establish some kind of relationship between income and mobility, although it is not a definitive indicator, helping to understand the possibilities of access to higher income areas and where consumption is proportional to the production of recyclable materials in greater quantity and value.

Finally, to minimize the effects of neighborhood size/road distribution relationships, the ratio of road length in kilometers per hectare, the number of inhabitants per kilometer of road, the estimate of recyclable materials generated per neighborhood, and the estimate of Recyclable materials generated per kilometer were quantified, making it possible to identify neighborhoods where more or less solid waste producing inhabitants are more accessible for collection and the different types of collection.

4. RESULTS ANALYSIS

Relief Analysis

By analyzing the hypsometric and slope map of Rio de Janeiro city, it is possible to verify a city subdivided into four morphological compartments delimited by an arched mountain relief, which begins in the vicinity of the Recreio neighborhood (southwestern portion - SW), near the sea, extending to Jacarepaguá (central portion), delimiting a rocky wall that separates the southern portion (S) from the northern portion (N) of the Municipality, extending to Alto da Boa Vista (southeast portion - SE) when it delimits the South and Center Zone (east compartment - L), in contact with Guanabara Bay (Figure 5).

This morphological configuration implies factors that have a direct impact on the urban dynamics of the city, because besides having a relief that makes the connection between the different spaces difficult, this relief presents very steep slopes in the hillsides of these hills, thus generating a significant urban void in the central portion of the municipality.

Thus, these relief conditions impose restrictions on the implementation of roads, directly interfering with the possibilities of the collection systems for the different relief conditions.

Population Analysis

Having analyzed the relevant macro characteristics of the city, it is important to understand how they influence the distribution of populations in their urban fabric.

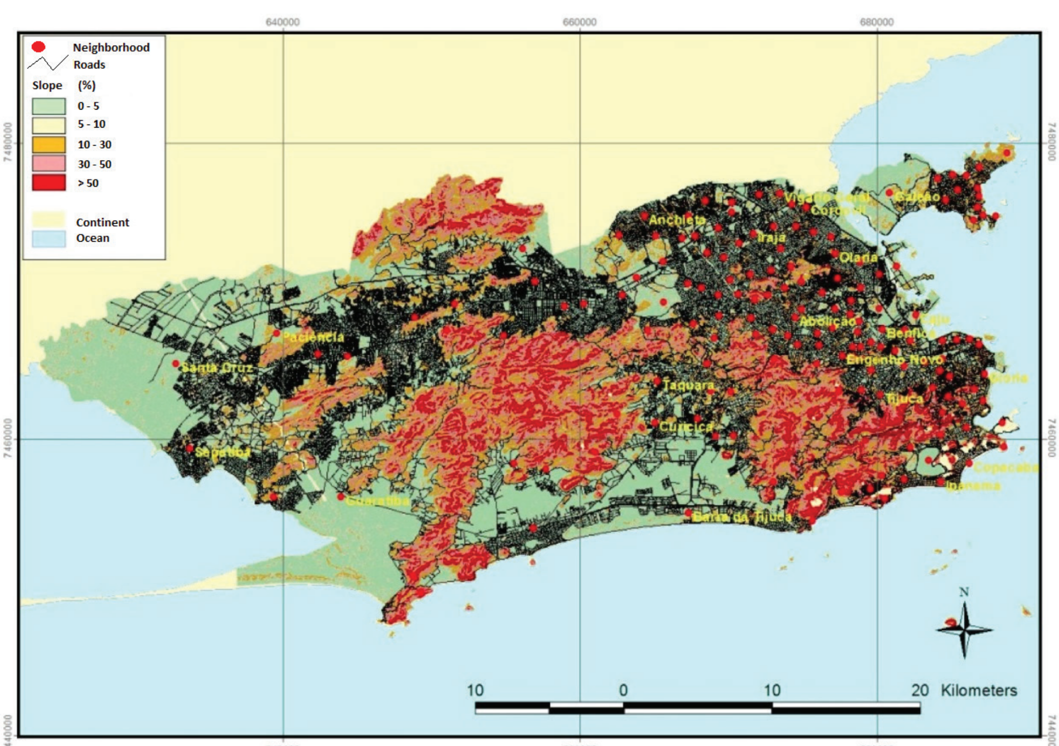

Figure 5. Hypsometric and slope map and its implications for the road and urban design of the city.

Source: Prepared by the authors from the cartographic bases of the IBGE (2010).

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Although not the most appropriate territorial unit, as it does not sufficiently disaggregate the information for more specific analysis, the neighborhood unit satisfactorily meets the objectives of this paper, as it allows identifying neighborhoods where the different collection systems may be better suited to the social and environmental conditions of the collection equipment used in the city.

A brief analysis of the spatial distribution of populations by neighborhood reveals larger numbers in Barra da Tijuca and Zona Sul (south portion - S) and Zona Oeste (northwest - NW) of the city (Figure 6). These results are justified because in these places there are neighborhoods with areas significantly larger than the neighborhoods of the central region and the North Zone (eastern - E and northeast - NE portion of the city). An isolated analysis of this representation could give a distorted view of the population distribution of service demands and collection systems for these areas.

In order to better understand the distribution of population by city neighborhoods, demographic and population densities per hectare per neighborhood were calculated (Figure 7), which revealed information that enables better planning regarding which selective collection system to adopt based on local characteristics.

The analysis of the demographic density map of the neighborhoods indicates a higher population concentration, exactly in the South, Center and North Zones (east portion - E) of the city, precisely because they are neighborhoods with smaller areas. Therefore, by means of demographic density (inhab/ha), it is verified that the eastern portion of the municipality concentrates most of the city's population, that is, a larger population contingent per area.

Road Density

The extension of the road system of the studied area is another factor to be considered in the planning of selective collection, and different models may be used depending on the region. Road extensions were calculated in meters per hectare which, like the population analysis, revealed a higher road density (capillarity) in the South, Center and North Zones of the city (Figure 8).

To refine the model, or to test it, the number of inhabitants per kilometer of roads was observed (Figure 9). The results of these analyzes revealed that the South, Center and North Zones of the city have a concentration of more viable areas, indicating neighborhoods where there is a larger population by road; in other words, it would mean many potentially recyclable wastes over short distances, which would be an important factor in locating waste picker ecopoints using low-cost collection equipment.

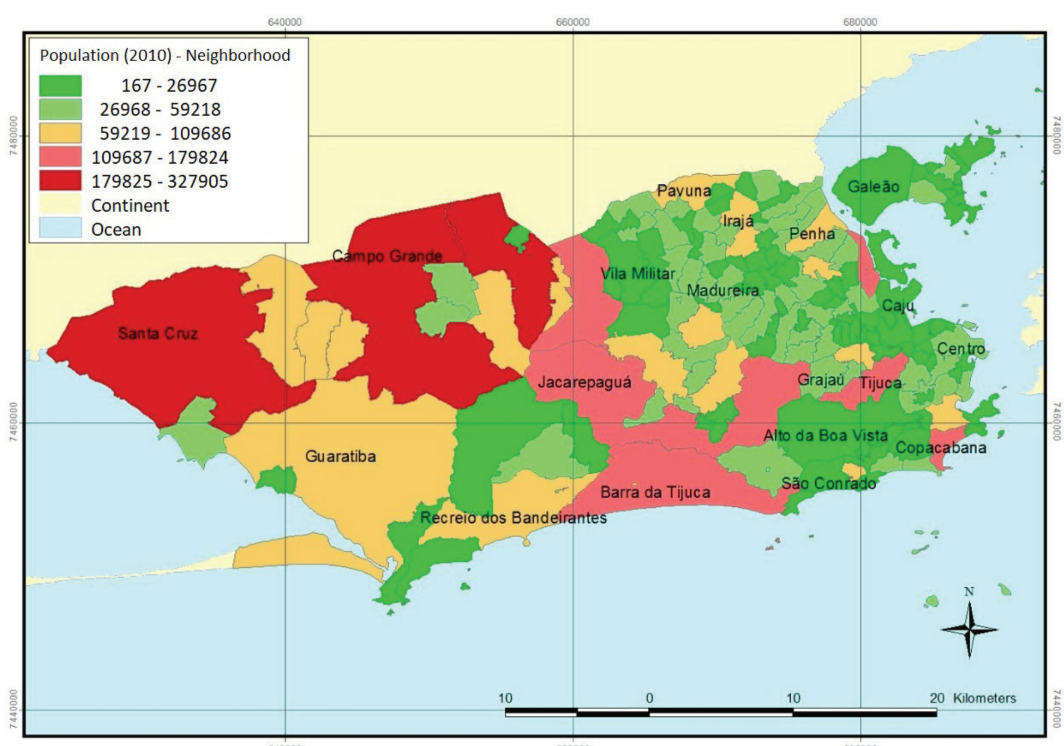

Figure 6. Population map by neighborhood

Source: Prepared by the authors from the IBGE census data (2010).

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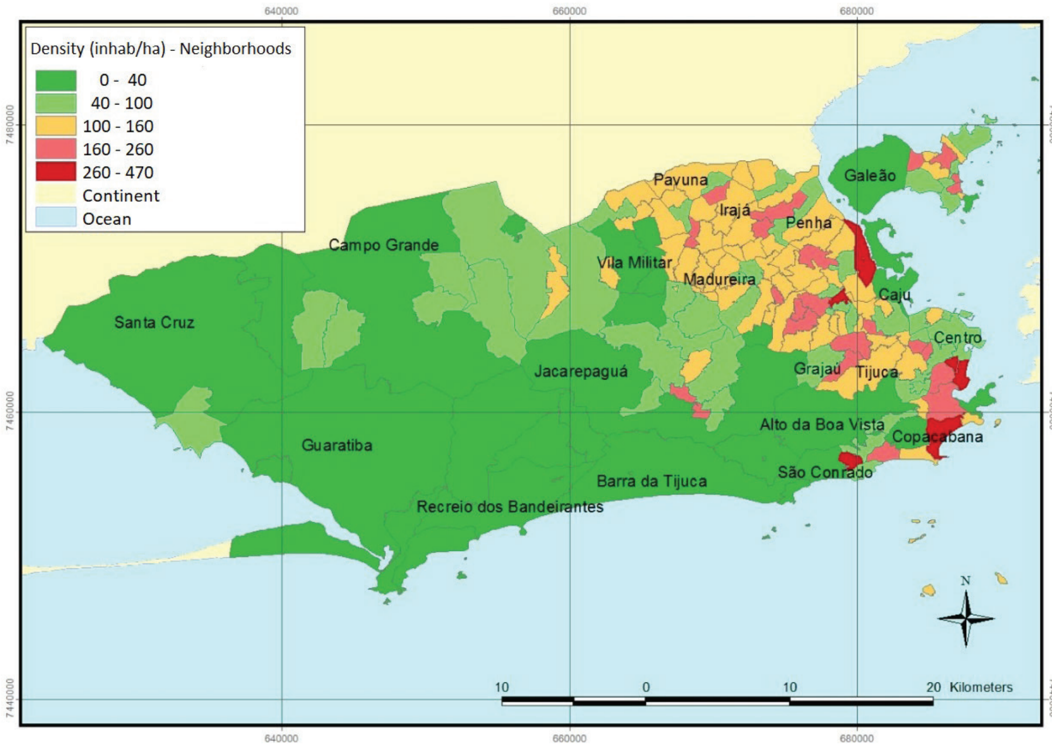

Figure 7. Demographic density map (inhab/ha) by Neighborhood
Source: Prepared by the authors from IBGE census data (2010).

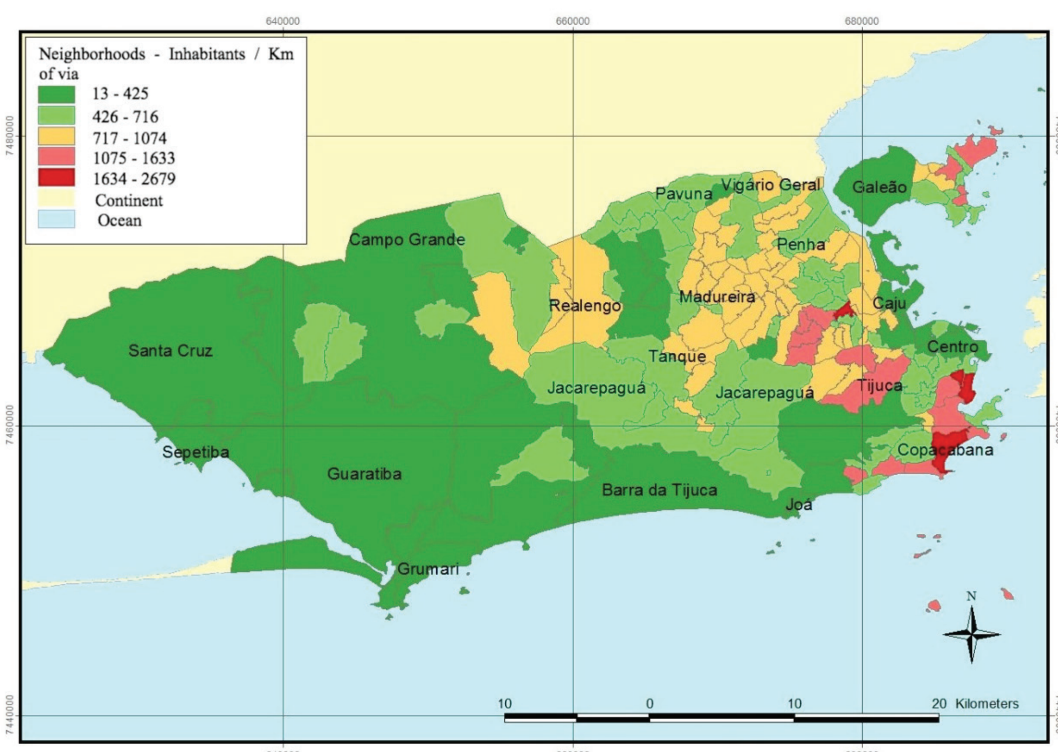

Figure 8. Map of road extensions in kilometers per hectare in the neighborhoods.
Source: Prepared by the authors from IBGE census data (2010).

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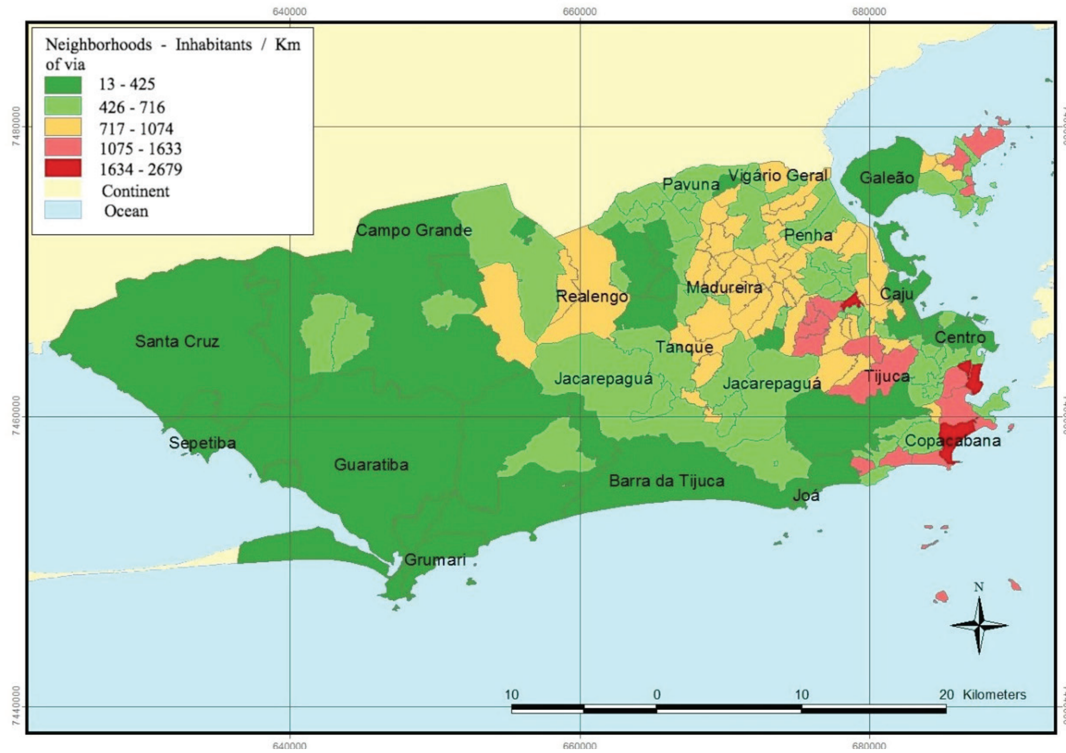

Figure 9. Map of the relationship of inhabitants by kilometers of road by neighborhoods.

Source: Prepared by the authors from IBGE census data (2010).

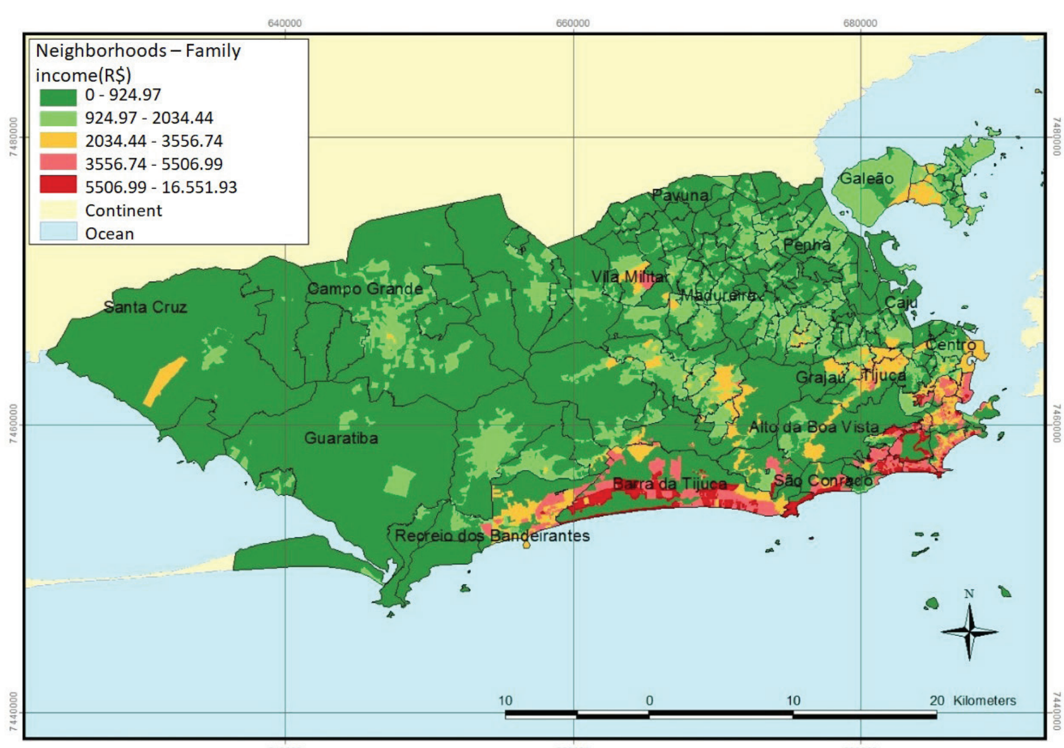

Figure 10. Map of Average Family Income (R $) by Neighborhood

Source: Prepared by the authors from IBGE census data (2010).

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Correlation between roads x income x recyclables generated

Considering that the highest demographic densities occur in the neighborhoods located in the South, Center and North Zones, it is possible to consider, by analogy, that these areas produce the largest amount of household solid waste per area and, consequently, the neighborhoods of Barra. Tijuca and West Zone produce a smaller amount per area, which justifies the adoption of appropriate collection systems for each location, able to better serve the population with fewer resources invested.

In addition to the density, the average income of the inhabitants of each neighborhood also deserves attention, as people with higher purchasing power end up generating more waste, especially the most valuable today in the recyclable production chain. Based on this premise, it was investigated the average income of families living in neighborhoods, disaggregated by census tracts, where it can be observed that the highest-income families live in Barra da Tijuca (southern portion of PA 4) and the neighborhoods near the seafront of the South Zone (Figure 10). Thus, it is clear that families closer to the sea have higher incomes and, consequently, can produce larger amounts of recyclable waste due to the greater potential for consumption of disposable products, but this type of inference is not definitive and should be the subject of more specific analysis.

Then, the road extensions in kilometers per neighborhood were analyzed (Figure 11). In this case, the size of the neighborhood showed an important element in explaining the quantitative. It is worth a brief reflection at this point, because neighborhoods with greater distance to the original core of the city, such as those located in Barra da Tijuca and the West Zone, have long linear axes to be accessed, creating long roads that burden the collection of solid waste in these areas. It is important to clarify that the best income urban fabric located in the southern portion (Barra da Tijuca and Zona Sul) of the municipality, near the beach, is quite dense and vertical on the narrow marine plain between the hills and the sea.

Finally, analyzes were made of the amount of recyclable materials generated per kilometer per day (Figure 12).

Considering that the Rio de Janeiro city PMGIRS presents the daily per capita values of household solid waste generated per inhabitant in each PA and that the proportion of effectively recyclable materials present in this waste is 25%, Table 2 presents the information referring to the population, area and demographic density of each PA and the expected amount of recyclable material to be generated in each PA of Rio de Janeiro.

Based on the quantification of mileage, population and quantity of recyclable materials per neighborhood, an analysis was made of the amount of recyclable materials generated per kilometer and per neighborhood (Figure 12), which indicates that the neighborhoods in the South Zone are the ones that generate the most materials per kilometer.

5. FINAL CONSIDERATIONS

One of the major constraints to the sustainability of selective collection is the transport of recyclable materials. Unlike conventional collection, where it is possible to maximize the space of the waste storage device through compaction, selective collection is costly because of the weight/volume ratio of the collected material, with volume limiting the collection capacity of the equipment used. Thus, the study of the costs, associated with the socio-environmental peculiarities of each location, is extremely important for the viability of the operation.

Analyzing operating costs, impacts on local traffic and collection efficiency, it is important to consider the use of different modes for selective collection in the city of Rio de Janeiro, considering that, due to its geography, infrastruc-

Table 2. Population, demographic density and amount of expected recyclable material to be generated in each planning area of Rio de Janeiro

Data		PA 1	PA 2	PA 3	PA 4	PA 5	TOTAL
Population	Inhab	307261	1006780	2399437	990545	1749659	6453682
	Area (Km²)	34,39	5,97	203,47	293,79	592,45	1130,07
	Density	8935	168640	11793	3372	2953	5711
Waste Collected	Ton/day HSW	375	709	1791	736	1280	4890
	Ton/day REC	94	177	448	184	320	1223
Per Capita REC (kg/inhab/day)		0,30	0,18	0,19	0,19	0,18	0,19

Source: Prepared by the author (2017).

HSW: Household Solid Waste; REC: Recyclable Waste

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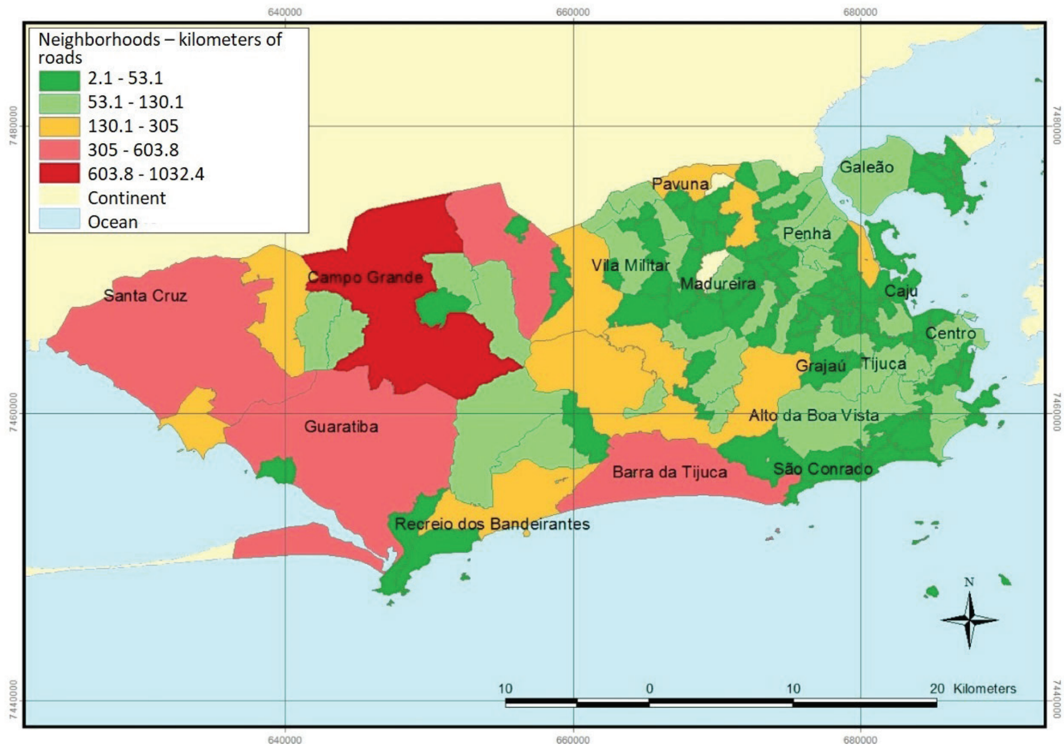

Figure 11. Map of road extensions in kilometers by neighborhood.

Source: Prepared by the authors from IBGE census data (2010).

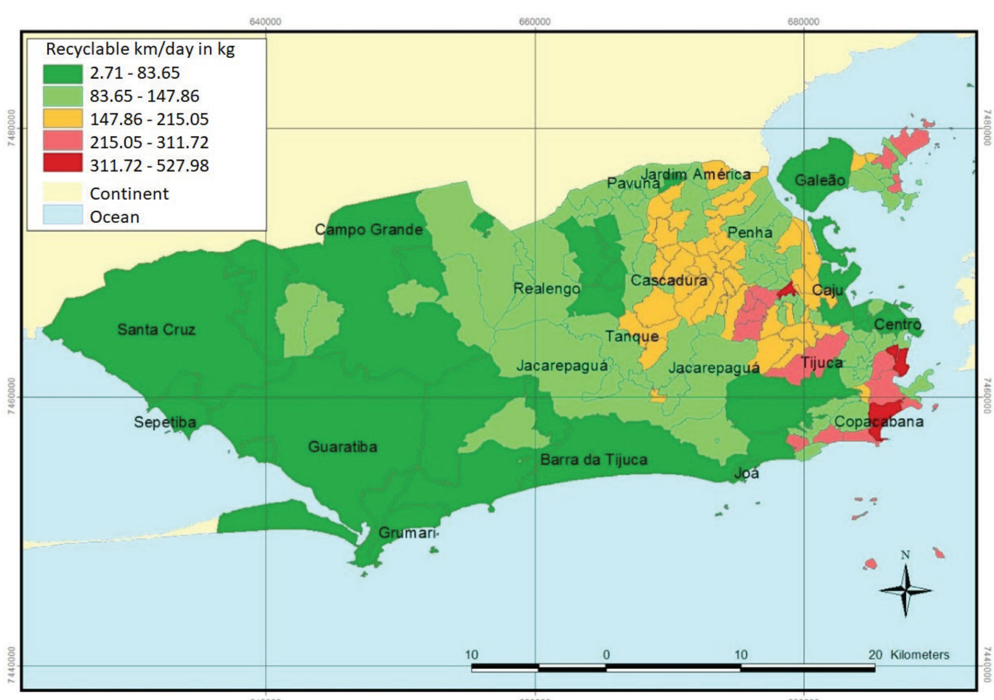

Figure 12. Number of recyclable materials generated per kilometer and neighborhood.

Source: Prepared by the author based on census data from IBGE (2010) and PMGIRS-RJ. (2015).

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ture, demographic density and socioeconomic profile of the population, the city has different regions that require different treatments to optimize the selective collection system. In particular, the choice of means of transport is fundamental in the collection planning, considering the physical, social and occupation characteristics by region.

As pointed out by Gil and Avila (2017), different modes are used for selective collection. The use of small vehicles associated with transshipment (transfer station) is an alternative to reduce collection costs, to have less impact on local traffic and to improve collection rates in densely populated areas where there is a larger population by road and, consequently, many potentially recyclable wastes over short distances, such as the districts of the South Zone, Central Region and North Zone (PA 1, 2 and 3). Transshipments can also be used as voluntary delivery points for various types of waste (recyclable, bulky and debris). For regions with larger areas, more roads and lower population density, the supply of recyclables per kilometer of roads is lower, as in the Barra da Tijuca and Zona Norte neighborhoods (PA 4 and 5). In this case, it is recommended to use trucks without compaction. It is worth noting, therefore, that the model of different modes in the selective collection transport system, as proposed here, can greatly contribute to the improvement of the current collection system, aiming at time, efficiency and resource saving.

Comlurb's current weekly door-to-door selective waste collection system serves 115 neighborhoods, collecting 1,700 tons per month of potentially recyclable materials from around 9,000 public places and 26 daily collection itineraries with duly identified and exclusive trucks for this service. The recyclable materials are placed in transparent plastic bags so that the collector can check the contents, avoiding the mixture of recyclable material with household waste. There is no need to separate the material, as this work will be done by the collectors' cooperatives, which will classify by industry type. The material collected is destined to 25 accredited waste picker cooperative centers. With this system there is the preservation of non-renewable natural resources, generating fronts of work and income, through the cooperative system, in which all collectors are paid through apportionment of the production of recyclables, thus avoiding the exploitation of labor; awareness, environmental education and improvement of urban cleanliness.

Finally, it is worth reiterating that a determining factor for good planning and execution of selective collection services is the participation of the population in the process, as presented by Bringhenti and Gunther (2011). Therefore, the lack of mobilization actions, continuous dissemination and information to the population is one of the main reasons for the low adherence of citizens.

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