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Drivers and Constraints to Participation in Residential Solid Waste Recycling Collection

Impulsionadores e Restritores à Participação na Coleta Seletiva Residencial de Resíduos Sólidos Urbanos

Impulsores y Limitadores de la Participación en la Recolección Selectiva Domiciliaria de Residuos Sólidos Urbanos

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Abstract

Research Purpose: The number of municipalities providing selective collection programs is increasing in Brazil. However, it is observed that a large amount of recyclable materials improperly destined to landfills, showing the low effectiveness of selective collection programs. This is due to the low popular adherence to the selective collection programs. This research aimed to identify the factors that drive and restrict popular participation in selective collection programs.

Theoretical framework: A theoretical model was proposed to identify which factors influence popular participation in selective collection programs, searching in the literature those factors that boost and restrict the individual's recycling behavior.

Methodology: The field study consists of an explanatory research of quantitative nature, conducted with residents of a large Brazilian capital, with the application of a questionnaire in person and online. The collected data were submitted to descriptive analysis, confirmatory factor analysis and Structural Equation Modeling.

Results: The hypotheses were accepted and their results confronted with the theory expressed. The results allowed us to identify the factors that drive and restrict popular participation in selective collection programs. Notwithstanding some limitations, it is noteworthy that the objectives were achieved.

Originality: This research innovates by employing a methodology, of a quantitative nature, with robust techniques of multivariate analysis and Structural Equation Modeling to support original theoretical aspects.

Theoretical and practical contributions: The findings of this research may change the way in which the dissemination and operationalization strategies of selective collection programs are defined. Other relevant social points, reasons that also do not refer to formal studies that can participate in a selective collection.

Keywords: Socio-economic impacts, Popular participation, Sustainable development, Urban solid waste management.

Resumo

Objetivo da pesquisa: O número de municípios que disponibilizam programas de coleta seletiva está aumentando no Brasil. No entanto, observa-se que uma grande quantidade de materiais recicláveis é destinada indevidamente a aterros sanitários, evidenciando a baixa efetividade dos programas de coleta seletiva. Este fato é ocasionado pela baixa adesão popular aos programas de coleta seletiva. Com base nessa problemática, a presente pesquisa teve por objetivo identificar os fatores que impulsionam e que restringem a participação popular em programas de coleta seletiva.

Enquadramento Teórico: foi proposto um modelo teórico para identificar quais fatores influenciam a participação popular em programas de coleta seletiva, buscando na literatura aqueles fatores impulsionadores e restritores do comportamento reciclador do indivíduo.

Metodologia: O estudo de campo consiste em uma pesquisa de natureza quantitativa, realizada com residentes de uma grande capital brasileira, com a aplicação de questionário de forma presencial e *on-line*. Os dados coletados foram submetidos à análise descritiva, análise fatorial confirmatória e Modelagem de Equações Estruturais.

Resultados: As hipóteses levantadas foram aceitas e seus resultados confrontados com a teoria expressa. Os resultados permitiram identificar a existência de fatores que impulsionam e que restringem a participação popular em programas de coleta seletiva. Apesar de algumas limitações, vale ressaltar que os objetivos foram alcançados.

Originalidade: Esta pesquisa inova por empregar uma metodologia, de natureza quantitativa, com técnicas robustas de análise multivariada e Modelagem de Equações Estruturais para apoiar os aspectos teóricos originais.

Contribuições teóricas e práticas: Os achados dessa pesquisa podem mudar a forma como são definidas as estratégias de divulgação e operacionalização dos programas de coleta seletiva. Outro ponto relevante refere-se à educação formal e social, já que o estudo apontou que esses motivos também não foram capazes de influenciar a participação popular em programas de coleta seletiva.

Palavras-chave: Impactos socioeconômicos, Participação popular, Desenvolvimento sustentável, Gestão de resíduos sólidos urbanos.

Resumen

Objetivo de la investigación: El número de municipios que ofrecen programas de recolección selectiva está aumentando en Brasil. Sin embargo, se observa que una gran cantidad de materiales reciclables son destinados indebidamente a rellenos sanitarios, evidenciando la baja efectividad de los programas de recolección selectiva. Este hecho se debe a la baja adhesión popular a los programas de recolección selectiva. A partir de esta problemática, la presente investigación tuvo como objetivo identificar los factores que impulsan y restringen la participación popular en los programas de recolección selectiva.

Marco teórico: se propuso un modelo teórico para identificar qué factores influyen en la participación popular en los programas de recolección selectiva, buscando en la literatura aquellos factores que potencian y restringen la conducta de reciclaje del individuo.

Metodología: El estudio de campo consiste en una encuesta de carácter cuantitativo, realizada con residentes de una gran capital brasileña, con la aplicación de un cuestionario presencial y online. Los datos recolectados fueron sometidos a análisis descriptivo, análisis factorial confirmatorio y Modelado de Ecuaciones Estructurales.

Resultados: Se aceptaron las hipótesis planteadas y se confrontaron sus resultados con la teoría expresada. Los resultados permitieron identificar la existencia de factores que incentivan y restringen la participación popular en los programas de recolección selectiva. A pesar de algunas limitaciones, cabe destacar que se lograron los objetivos.

Originalidad: Esta investigación innova al emplear una metodología, de carácter cuantitativo, con técnicas robustas de análisis multivariado y Modelado de Ecuaciones Estructurales para sustentar los aspectos teóricos originales.

Contribuciones teóricas y prácticas: Los hallazgos de esta investigación pueden cambiar la forma en que se definen las estrategias de difusión y operacionalización de los programas de recolección selectiva. Otros puntos sociales relevantes, razones que tampoco se refieren a estudios formales que puedan participar en una recolección selectiva.

Palabras Clave: Impactos socioeconómicos, Participación popular, Desarrollo sustentable, Gestión de residuos sólidos urbanos.

1 INTRODUCTION

According to the What Waste 2.0 Report (World Bank, 2018), our planet generates approximately 2 million tons of solid waste annually, with at least 33% not being properly treated. The report predicts that factors such as rapid urbanization, population growth, economic development, and increased consumption will lead to a 70% increase in solid waste generation over the next 30 years, reaching a total of 3.4 million tons per year. Several authors (e.g., Ribeiro & Besen, 2007; Jacobi & Besen, 2011; Neves & Castro, 2012; Abramovay, Speranza, & Petitgand, 2013; Frota et al., 2016; World Bank, 2018) agree that these factors, observed in recent decades and projected for the future, call for the development and implementation of differentiated collection and treatment systems, as well as environmentally safe disposal methods for Urban Solid Waste (MSW).

The increasing generation of urban solid waste (MSW), driven by development models that rely on readily available industrial products packaged in disposable materials and planned obsolescence, leads to wastage of energy and natural resources. It also contributes to the production of polluting waste, compromising the soil, air, groundwater, surface water, and oceans (Jacobi & Besen, 2011; Neves & Castro, 2012; Braga & Mereilles, 2017). The consequences are evident in intensified floods and droughts, the proliferation of disease-carrying vectors, unsanitary street waste collection, and inadequate final disposal of MSW. These factors unquestionably result in environmental degradation, affecting natural resources and compromising people's quality of life (Ribeiro & Besen, 2007; Jacobi & Besen, 2011; Neves & Castro, 2012; Frota et al., 2016).

Beyond the academic sphere, society is increasingly concerned about environmental quality, recognizing the production of urban solid waste as a major problem (Jacobi &

Besen, 2011; Neves & Castro, 2012; Frota et al., 2014; Seiffert, 2014). From the perspective of urban sustainability, the recycling process plays a vital role in reducing MSW, minimizing environmental impacts, and addressing health issues. However, waste segregation at the source and the existence of selective collection programs are essential (Bringhenti, Zandonade, & Günther, 2011). In Brazil, Law No. 12,305/10 stipulates that waste management responsibilities must be shared among the government, society, and companies involved in the manufacturing and sale of products and packaging that are discarded after consumption (Brasil, 2010; Braga & Meirelles, 2017).

Therefore, it is crucial to investigate the factors associated with public participation in selective collection programs to understand what motivates and hinders individuals' pro-environmental behavior in terms of separating recyclable materials. These practices are essential for implementing and advancing solid waste selective collection programs. However, it is important to note that the effectiveness of these actions relies heavily on citizen involvement (Bringhenti & Günther, 2011; Góes, 2011; Neves & Castro, 2012; Salgado, Batista, & Aires, 2013; Souza, Lacerda, Silva, & Silva, 2014; Corrêa, Hernandez, Santos, Santos, Colares, & Corrêa, 2015; Marques, Vasconcelos, Guimarães, & Barbosa, 2017; Bicalho & Pereira, 2018).

Despite some efforts to understand the determinants of citizens' recycling behavior (McCarty & Shrum, 1994; Hornik, Cherian, & Madansky, 1995; Franco & Huerta, 1996; Passafaro & Livi, 2017; Nguyen, Zhu, & Le, 2019), there is still a significant gap in the literature on this subject. Most studies divide these determinants into incentive factors and barriers, attempting to establish intrinsic or extrinsic variables, values, and social norms. However, few studies approach it systematically or apply it to the behavioral conditions of emerging economies. This research aims to address this gap by developing a recycling behavior model based on previous studies, with a particular focus on the behavior of urban recyclers in emerging economy countries. It seeks to answer the research question: What factors positively and negatively influence adherence to selective collection programs for urban solid waste? Additionally, it aims to achieve the following specific objectives: i) identify the driving and limiting factors for pro-environmental behavior related to popular participation in selective collection programs; ii) determine the most significant factors that explain urban citizens' participation in selective collection programs.

2 THEORETICAL BACKGROUND

In Brazil, the management of urban solid waste (MSW) is still below expectations. According to data from the National Sanitation Information System (SNIS, 2019), 41.9% of Brazilian municipalities rely on dumps as a method of waste disposal, while 21.8% use controlled landfills and 23.3% deposit waste in sanitary landfills. Diniz and Abreu (2018) attribute this situation to issues such as the limited availability of financial, human, and technological resources for MSW management. The authors also highlight that the high rate of improperly disposed MSW in dumps and uncontrolled landfills is a result of the inadequate technical and administrative training of public officials, as well as the weak organization of environmental and municipal agencies responsible for waste collection and disposal.

Lopes and Lima (2014) note that integrated solid waste management begins with the process of waste generation, which is influenced by various factors such as income, seasons, consumer behavior, lifestyle, population movements during holidays and weekends, and the introduction of new packaging methods, including the growing use of non-returnable packaging. In this context, integrated MSW management can be understood as the systematic administration of activities involving waste separation, storage, collection, transportation, transfer, processing, treatment, and final disposal (Diniz & Abreu, 2018). Mello and Sehnem (2016) add that MSW management encompasses control, prevention, and reduction of waste generation, aiming to promote sustainable consumption habits and encourage recycling and reuse.

Within the framework of integrated urban solid waste management, selective collection plays a crucial role, involving the inclusion of recyclable material collectors, as outlined in the fundamental goals of the National Solid Waste Policy (PNRS) – art. 7, XII; art. 17, V (Diniz & Abreu, 2018; Maiello, Britto, & Valle, 2018). Implementing the principles of integrated MSW management implies reducing the negative impacts resulting from inadequate waste management and seeking solutions that bring social, economic, and environmental benefits. Selective collection emerges as an alternative to prevent recyclable materials from ending up in landfills or dumps, allowing them to be reused as raw materials in production processes, thus preserving natural resources. It also creates employment opportunities and generates income (Andrade & Ferreira, 2011; Ferreira, 2018; Maiello, Britto, & Valle, 2018). Therefore, selective collection is essential for the effectiveness of integrated solid waste management. However, several influential factors related to the environment and community behavior need to be considered to strike a balance in this process.

2.1 Recycling Behavior: Driving Factors

Pro-environmental behavior encompasses the interaction between human behavior and the environment in which it occurs. This dynamic can be understood on an individual level, where individuals are aware of and take responsibility for their environmental impact, as well as within a social context that considers determinants such as work, income, health, and education (Corral-Verdugo, 2005). Pro-environmental behavior entails various environmentally conscious actions, including reducing consumption, using finite natural resources wisely, and engaging in initiatives for waste management and preservation (Dias, 2009). Therefore, effective MSW management and the adoption of selective collection align with pro-environmental behavior. Considering that behavior is influenced by individual and collective factors, the literature identifies various influential factors that shape individuals' behavior, such as environmental concern (Bringhenti & Günther, 2011), cleanliness of streets and the city (Souza et al., 2014), awareness of selective collection (Giaretta, Fernandes, & Phillipi Júnior, 2012), basic and civic education (Neves & Castro, 2012), local identity and appreciation (Giaretta, Fernandes, & Phillipi Júnior, 2012), social pressure (Bringhenti & Günther, 2011), among others. Based on these factors that drive pro-environmental behavior, the following hypothesis is proposed:

H1: Pro-environmental driving factors positively influence the intention to participate in Selective Collection Programs (SCP).

It's worth noting that several studies have focused on understanding these driving factors. Some authors (Giaretta, Fernandes, & Phillipi Júnior, 2012; Neves & Castro, 2012) relate these factors to the environment, based on the premise that not only do human beings impact the physical environment, but environmental conditions also shape communities. On the other hand, some authors also examine operational aspects as drivers (Possidonio Júnior & Agnol, 2013; Corrêa et al., 2015), considering operational aspects as infrastructure adequacy, dissemination efforts, and the establishment of specific days and times for selective collection, for example. Therefore, it is proposed to further segment the first hypothesis as follows:

H1a: Environmental driving factors positively influence the intention to participate in SCP;

H1b: Operational driving factors positively influence the intention to participate in SCP.

2.2 Recycling Behavior: Restricting Factors

Just as positive aspects can enhance the relationship between the environment and society, negative factors can hinder pro-environmental behavior. Once again, these factors can stem from individuals, such as a lack of environmental awareness (Giaretta, Fernandes, & Phillipi Júnior, 2012; Salgado & Batista, 2013) or the time and effort required for separating and cleaning recyclable materials (Bringhenti & Günther, 2011). Additionally, there are collective factors, such as insufficient communication about the benefits of selective collection (Corrêa et al., 2015), inadequate promotion of selective collection programs (Marques et al., 2017), or mistrust in the actions of public authorities (Giaretta, Fernandes, & Phillipi Júnior, 2012). It is also hypothesized that these negative factors can be exacerbated by the need to adapt domestic structures, which may lead to difficulties in correctly separating materials or a lack of appropriate storage facilities (Bringhenti & Günther, 2011). Therefore, the following hypotheses are proposed:

H2: Restrictive operational factors negatively influence the intention to participate in SCP;

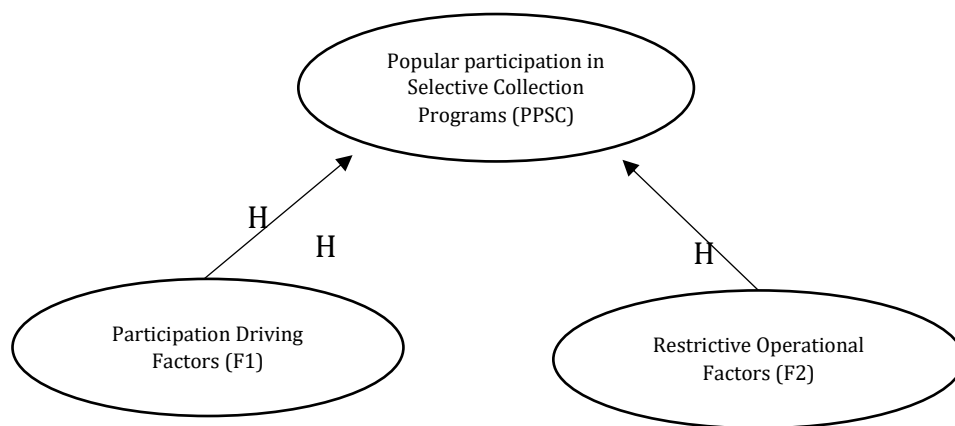
H3: The need for adaptation negatively influences the intention in relation to restrictive operational aspects.

2.3 Research Framework

According to the literature, several variables that promote or hinder population participation in selective collection programs have been identified. These dimensions can be classified into two constructs, as depicted in Figure 1: (a) Drivers of popular participation in selective collection programs, and (b) Restrictors of popular participation in selective collection programs. Both constructs encompass a significant number of variables that influence people's decision to adhere or not to selective collection programs.

The framework proposed (Figure 1) is based on the understanding that popular participation is crucial for the effectiveness of selective collection programs (PPSC), as evidenced by numerous studies (Bringhenti & Günther, 2011; Góes, 2011; Neves & Castro, 2012; Salgado, Batista, & Aires, 2013; Souza et al., 2014; Corrêa et al., 2015; Marques et al., 2017; Bicalho & Pereira, 2018). The objective of this framework is to identify the variables that comprise the construct of positive influences on participation in selective collection programs (F1) and the variables that form the construct of factors that restrict participation (F2). Furthermore, these variables and their relationships are supported by various authors (see Supplementary Material I).

Figure 1 Theoretical Framework



Source: Elaborated by the authors.

3 METHODOLOGY

The present study has an explanatory-quantitative nature and employed field research to gather primary data through a questionnaire (Vergara, 2004; Prodanov, 2013). The target population consisted of residents of the municipality of Fortaleza, which has a total population of approximately 2.5 million inhabitants and is densely populated (Instituto de Pesquisa Econômica do Ceará - IPECE, 2017). The sample for this study was non-probabilistic and selected for accessibility (Vergara, 2009; Malhotra, 2012), assuming an infinite population (Martins & Theóphilo, 2009). The sample size was determined based on a confidence level of 95% ($Z = 1.96$), a sampling error of 5% ($d = 0.05$), and proportions (p and $q = 0.50$), resulting in a sample of 384 respondents.

The research instrument used in the study consisted of two parts. The first part included sociodemographic questions to categorize the respondents, while the second part consisted of questions for the intended analyses (indicators mentioned in Supplementary Material I). Each question was presented as a statement, and respondents were asked to indicate their level of agreement or disagreement on a five-point Likert-type scale, where 1 represented total disagreement and 5 represented total agreement. The questionnaires were administered in person (printed) and online through Google Forms, covering residents of the municipality of Fortaleza and distributed among the neighborhoods corresponding to the seven Regional Executive Secretaries (RES), which are part of the municipal management structure.

Initially, 437 responses were obtained through Google Forms, but 62 observations were excluded as they fell outside the research scope. Additionally, 66 observations were obtained from in-person questionnaires. While no missing data were identified, 31 atypical observations with a standard deviation greater than three points were removed (Corrar, Paulo, & Dias Filho, 2007; Hair et al., 2009).

The final sample consisted of 410 valid observations. The respondents ranged in age from 19 to 76 years, and no households with children under 18 years of age were observed. The sample was predominantly female (61.50%), with the majority falling within the 30 to 35 years age group (31.29%). A significant proportion had a high level of education (77.56%) and an average household size of up to three people (29.71%). The majority of respondents had high individual and family income, exceeding five minimum wages (27.44% and 53.97%, respectively). Furthermore, 46.26% of respondents resided in affluent neighborhoods in the city.

The reliability of the research instrument (Table 1) was assessed using Cronbach's alpha coefficient (0.809) (Hair et al., 2009), indicating sufficient internal consistency for conducting statistical treatments, including Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).

The first inferential treatment applied in the theoretical model was Exploratory Factor Analysis (EFA), as it aimed to identify the underlying factors that explain popular participation in selective collection programs by reducing the number of independent variables in constructs F1 and F2 into more general factors (Corrar, Paulo, & Dias Filho, 2007; Hair et al., 2009). Following the extraction of factors through EFA, Confirmatory Factor Analysis (CFA) was conducted to validate the number of factors (or new constructs) and assess the loadings of the observed variables (indicators) based on the theoretical foundation (Malhotra, 2012). CFA employs Structural Equation Modeling (SEM) to confirm the proposed model. SEM is a statistical modeling approach that aims to explain relationships between multiple variables, describing all the relationships between the constructs (dependent and independent variables) involved in the analysis (Hair et al., 2009).

Finally, the model (Figure 1) was analyzed using the results obtained from CFA to examine how the independent variables are related to the dependent variable. This involved utilizing SEM to analyze the measurement model, which illustrates how the measured variables combine to represent the constructs, as well as the structural model, which demonstrates the associations between the constructs (Hair et al., 2009). The data collected were processed and analyzed using statistical software such as SPSS® (Statistical Package for Social Sciences v. 26) and AMOS® (v. 24) (Byrne, 2013).

Table 1 Research Instrument

Code	Item	Construct	Cronbach's alpha
V1	According to the conditions presented by the selective collection programs, you feel motivated to participate.	Intention to Participate - PPSC	-
V2	Concern for the environment and conservation of natural resources.	Drivers of popular participation in selective waste collection programs (Referring to Enabling Environments and Operational Aspects)	0.720
V3	Improvement of public health conditions, quality of life, and urban cleanliness.		
V4	Space savings in landfills, increasing their lifespan and reducing the environmental impacts caused by them.		
V5	Increased societal awareness of environmental issues, pressuring people to participate in selective collection programs.		
V6	Ease of sharing the procedures for selecting recyclable materials with other household members.		
V7	Higher levels of education and literacy among individuals.		
V8	Knowing that selective collection programs improve the social, environmental, and economic conditions of the communities involved.		
V9	Reducing risks represented by improper handling and disposal of household waste to the general population and urban cleaning workers.		
V10	Receiving financial benefits based on the quantity of recyclable materials delivered to the selective collection program.		
V11	Selective collection programs that offer good operational infrastructure, promoting awareness campaigns, community mobilization, and dissemination of results achieved through the collection of recyclable materials.		
V12	Having defined days and times for the selective collection to take place.		
V13	Realizing that recyclable materials have the same fate as regular waste.		
V14	Not knowing that recyclable materials incorrectly disposed of in landfills harm the environment.		
V15	Requiring time and attention to properly carry out selective collection.		
V16	Not being able to adequately identify recyclable materials in household waste.		
V17	Lack of appropriate space to store recyclable materials at home.		

V18	Lack of interest in the practice due to unfamiliarity with the selective collection programs available in the neighborhood or their non-existence.	Operational Aspects and the Need for Adaptation).
V19	The need to acquire double the materials (containers and plastic bags) for home-based selective collection.	
V20	Lack of environmental awareness and education, low cultural and educational levels among the population.	
V21	Deficient infrastructure of selective collection programs, with drop-off points located far from residential areas.	
V22	Lack of any form of reward to incentivize people's participation in selective collection programs.	
V23	Lack of promotion of selective collection programs, as well as the benefits achieved through selective collection.	
V24	Lack of guidance regarding the selective collection process.	
V25	Lack of trust in selective collection programs developed by the government.	

Source: Elaborated by the authors.

4 RESULTS AND DISCUSSIONS

To conduct an exploratory analysis, the collected data from the field study were subjected to Exploratory Factor Analysis (EFA). The purpose of this analysis was to reduce the number of items in the scales used with the research participants and identify latent variables associated with the proposed theoretical model. The aim was to align the factors obtained and their labels with the theoretical aspects derived from the literature.

The EFA was performed on 24 observable variables, which served as the independent variables in the study. These variables were divided into two groups: driving factors (consisting of 11 items) and restricting factors (consisting of 13 items). Each group was analyzed separately. Through the EFA, three factors associated with the driving group and three factors associated with the restricting group were identified. To meet the criteria for EFA adequacy (i.e., Kaiser-Meyer-Olkin (KMO) measure, Bartlett's Sphericity test, anti-image matrix, commonality, and factor loading), two variables (V5 and V10) were eliminated from the driving group, and three variables (V18, V20, and V22) were eliminated from the restricting group.

After conducting the exploratory analysis on the sets of investigated items, the two-step modeling approach proposed by Anderson and Gerbing (1988) was followed to construct the structural path diagram. Initially, a measurement model was created to assess the overall fit of the remaining variables. The results of Confirmatory Factor Analysis (CFA) indicated that the model composed of the six constructs identified in the EFA had satisfactory fit indices. However, two constructs did not exhibit adequate indices of convergent and discriminant validity. Consequently, a new measurement model was

proposed, comprising four constructs: two related to driving factors and two related to restricting factors.

The measurement model included the following constructs: Environmental Driving Factors (composed of variables V2, V3, V4, and V8), Operational Driving Factors (consisting of variables V11 and V12), Restrictive Operational Factors (comprising variables V21, V23, V24, and V25), and Need for Adequacy (including variables V15, V16, V17, and V19). This measurement model demonstrated satisfactory fit indices, and the constructs achieved adequate coefficients in terms of convergent and discriminant validity (as shown in Table 2).

Table 2 Indicators of convergent and discriminant validity

Construct	CR	AVE	MSV	ASV	OR	AI	OI	NA	Alpha
ROF¹	0.784	0.482	0.261	0.147	0.694				0.775
EDF²	0.757	0.441	0.281	0.122	0.287	0.664			0.728
ODF³	0.682	0.525	0.281	0.142	0.310	0.530	0.725		0.661
NA⁴	0.736	0.411	0.261	0.104	0.511	0.048	0.223	0.641	0.735

Legend: ¹ Restrictive Operational Factors; ² Environmental Driving Factors; ³ Operational Driving Factors; ⁴ Need for Adequacy.

Source: Elaborated by the authors.

In terms of convergent validity, the constructs were assessed based on the composite reliability (CR) and average variance extracted (AVE) parameters. According to the criteria established by Fornell and Larcker (1981) and Garver and Mentzer (1999), a CR value above 0.7 and an AVE value exceeding 0.5 are considered satisfactory. However, Fornell and Larcker (1981) suggest that AVE values greater than 0.4 are acceptable if the CR values exceed 0.7. It is important to note that only the Restrictive Operational Factors construct had a slightly unsatisfactory CR value, although it was close to 0.7. However, considering the theoretical justification for each construct, it was decided to retain all constructs in the analysis.

For discriminant validity, the square root of the AVE index for each construct was found to be greater than the correlation between them. Additionally, the variance extracted from each construct was higher than the maximum shared squared variance (MSV) and the shared mean squared variance (ASV). These findings provide evidence of discriminant validity.

Once the measurement model's fit and construct validity were confirmed, the structural path diagram was constructed based on the theoretical relationships derived from the literature. Table 3 presents the key adjustment measures for the proposed structural model.

Table 3 Structural model fit measures

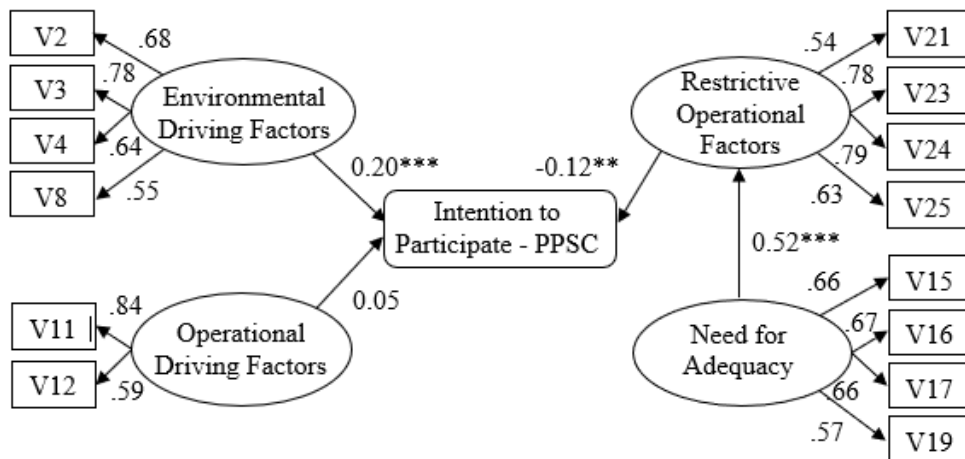
Absolute Adjustment		Incremental Adjustment	Parsimony
GFI	RMSEA	CFI	CMIN/DF
0.931	0.066	0.904	2.791

Legend: GFI – Goodness of Fit Index; RMSEA – Root Mean Square Error of Approximation; CFI – Comparative Fit Index; NFI – Normed Fit Index; TLI – Tucker-Lewis Index; CMIN/DF – Minimum Discrepancy/Degrees of Freedom.

Source: Elaborated by the authors.

According to Table 3, the adjustment indicators reached satisfactory values (Schumacker & Lomax, 2004; Hair et al., 2009; Byrne, 2013), enabling the analysis of structural relationships. The path diagram was constructed using the exogenous variables Environmental Driving Factors, Operational Driving Factors, Restrictive Operational Factors, and Need for Adequacy in the structural model. The dependent variable of the study, indicating the Intention to Participate in Selective Collection Programs, was represented by variable V₁ (According to the conditions presented by the selective collection programs, do you feel motivated to participate?) (Figure 2). It is important to note that although the construct consists of only one variable, Bergkvist and Rossiter (2007) suggest that measuring a latent variable with a single item is acceptable and does not undermine the proposed theoretical model, as long as the object of analysis is clear and does not require extensive speculation from the respondents, as indicated in the construct.

Figure 2 Structural Model Path Diagram



Caption: *** Significant at 1%; ** Significant at 5%;

Source: Elaborated by the authors.

It is worth mentioning that the relationship between the Need for Adequacy construct (Restricting Factor) and Intention to Participate – PPSC was redefined in order to achieve satisfactory adjustment coefficients in the structural model. The research hypotheses, derived from the analysis of the literature as well as the respecified structural model, were tested accordingly (Table 4).

Table 4 Hypothesis tests of the theoretical model

Hi	Structural Paths	Non-Pad coefficients.	Standard Error	Pad. Coefficients (β)	P	Results
H _{1a}	Environmental Driving Factors → Intention to Participate – PPSC	0.835	0.298	0.202	0.005***	Accepted
H _{1b}	Operational Driving Factors → Intention to Participate – PPSC	0.135	0.208	0.047	0.517	Refuted
H ₂	Restrictive Operational Factors → Intention to Participate – PPSC	-0.330	0.153	-0.118	0.031**	Accepted
H _{3a}	Need for Adequacy → Operational Restrictor	0.273	0.042	0.521	0.000***	Accepted

*** Significant at 1%; ** Significant at 5%.

a. Relationship from the respecified theoretical model.

Source: Elaborated by the authors.

The literature (e.g., Bringhenti & Günther, 2011; Giaretta, Fernandes, & Phillipi Júnior, 2012; Salgado & Batista, 2013; Corrêa et al., 2015; Marques et al., 2017) on solid waste management has identified various aspects that directly influence people’s pro-environmental behavior and their intention to participate in selective collection programs. While these aspects are conceptually independent, they can be grouped into two categories based on their positive or negative relationship with the variable “Intention to Participate – PPSC”. Out of the 24 aspects identified in the literature, 14 were classified into four factors that represent different properties within the spectrum of initially theorized relationships. These constructs highlight the complexities associated with the intention to participate in selective collection programs, following both qualitative and quantitative validation parameters.

Descriptive statistics were used to fulfill the first specific objective, revealing that there was more agreement than disagreement among respondents for both the dependent variable and the independent variables (Supplementary Material I). Most items reached a value equal to five ($M_o = 5$), indicating a high level of agreement. The second and third objectives were achieved through exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), respectively. The results of the EFA showed that most items related to the driving and restricting constructs were grouped into similar factors, allowing for interpretation according to the underlying theory. The CFA validated the factors that constitute the theoretical model definitively. Finally, the fourth specific objective was accomplished by testing the theoretical model (Figure 1) using Structural Equation Modeling (SEM), which examined the factors influencing the dependent variable.

Among the four factors identified in the exploratory analysis, two of them, namely the “Environmental Driving Factors” and “Operational Driving Factors”, conceptually have a positive relationship with the “Intention to Participate – PPSC”. These results differ from other studies (ex. Dhokhikah, Trihadiningrum & Sunaryo, 2015) that found socioeconomic characteristics to have less influence on community participation in waste reduction. Conversely, the “Restrictive Operational Factors” and “Need for Adequacy” constructs demonstrate a negative conceptual relationship with the “Intention to Participate – PPSC”. Studies (e.g., Timlett & Williams, 2008) have also identified cost as an operational factor that restricts behavioral changes, indicating that higher investment costs for improvements in motivation and operational teams responsible for recyclable

collection result in lower social participation. However, the original theoretical model of this research required structural refinements to account for these conceptual nuances.

The results from the analysis of structural paths confirm the hypotheses derived from the literature, indicating the presence of driving and restricting factors for the intention to participate in selective collection programs (H₁ and H₂). Specifically, the “Environmental Driving Factors” construct had a positive impact on the “Intention to Participate – PPSC” (H_{1a} - $\beta = 0.202$; $p = 0.005$). However, the effect of the “Operational Driving Factors” construct on the dependent variable was not significant (H_{1b} - $\beta = 0.047$; $p = 0.517$). These results differ from other studies that emphasize the importance of operational practices, such as public education programs on waste prevention and reuse, to enhance people’s engagement in selective collection participation (e.g., Ezeah & Roberts, 2012; Dhokhikah, Trihadiningrum, & Sunaryo, 2015).

The results of the study suggest that the respondents’ primary concern is focused on environmental conservation and the well-being of the population, including aspects related to public health, quality of life, and urban cleanliness. Furthermore, joining selective collection programs poses challenges that extend beyond environmental considerations, requiring technical, organizational, and economic solutions (Ribeiro & Besen, 2007). Technical solutions involve addressing issues such as lack of qualification or training, while organizational solutions involve improving work organization and cooperative practices. Economic challenges relate to the competitive market for recyclable materials. Cooperative practices in solid waste management are emphasized as important for sustainability and reducing costs associated with waste disposal in sanitary landfills, as well as mitigating environmental impacts caused by improper waste disposal (Moraes et al., 2022).

On the other hand, operational information such as collection schedules or dissemination of sanitary action results does not significantly impact the population’s intention to participate. This lack of relationship may be attributed to the high degree of exposure the population already has to such information. Additional disclosures are unlikely to increase interest since important information like collection days and times are already well-known and integrated into their daily lives.

Although the operational aspect does not directly enhance the intention to participate – PPSC, the “Restrictive Operational Factors” construct negatively impacts the dependent variable (H₂ - $\beta = -0.118$; $p = 0.031$). Investment cost, among other operational constraints identified in the literature (Timlett & Williams, 2008), has been found to influence social participation, suggesting that simple and low-cost methods are more effective in driving behavioral change. Another construct, “Need for Adequacy”, represents variables that restrict popular adherence to selective collection programs. Notably, in the structural model, a causal relationship was established between the “Need for Adequacy” and “Restrictive Operational Factors” constructs. These constructs exhibit a significant and positive relationship (H₃ - $\beta = 0.521$; $p = 0.000$), indicating a direct impact of the exogenous variable on the endogenous one.

The findings indicate that factors such as inadequate infrastructure (e.g., lack of drop-off points), absence of incentives for participation, and insufficient guidance in the collection process negatively affect the population’s intention to participate in selective collection programs. These results counter the lack of significant effect observed in the test of hypothesis H_{1b}, suggesting that the population values assertive actions related to

waste collection. While disclosing operational information had no significant effect on respondents' intentions (H_{1b}), the absence of operational aspects such as infrastructure, incentives, and guidance did have a significant impact (H₂).

It is important to highlight that the absence of operational aspects (Operational Restrictor) is positively influenced by attributes such as incompetence in correctly separating materials, lack of suitable processing facilities at home, and the need for time and attention for selective collection. These attributes collectively represent the Need for Adaptation, particularly from the perspective of the population itself. In other words, the perception of a lack of domestic infrastructure indicates that the public sector also does not contribute to strengthening the selective collection infrastructure. As a result of the relationship between Operational Restrictor and Intention to Participate - PPSC, there is an increase in the lack of interest in participating in the selective collection process.

5 CONCLUSION

This study aimed to investigate the factors that influence and restrict popular participation in selective collection programs. The research question was successfully addressed, and the objectives of the study were achieved. Factors that drive (Environmental Driving Factors and Operational Driving Factors) and restrict (Restrictive Operational Factors) popular participation in selective collection programs were identified, along with statistically significant relationships between these factors and the dependent variable (Popular Participation in Selective Collection Programs), which aligns with previous authors' findings (Supplementary Material I).

This research innovates by employing a quantitative methodology with robust multivariate analysis techniques and Structural Equation Modeling to support the theoretical aspects. The effectiveness of these techniques in providing satisfactory results contributes to a better understanding of the low popular adherence to selective collection programs. The findings of this study have important implications for program managers. It suggests redefining target audiences, as the majority of respondents were female, indicating that women often assume the role of household waste management. Thus, managers can develop more specific outreach campaigns targeted towards male audiences.

Formal and social education was also found to have limited influence on popular participation in selective collection programs. Therefore, program managers should emphasize strategies that address environmental factors, such as raising awareness about environmental concerns, conservation of natural resources, and reduction of landfill-related environmental impacts. Additionally, operational factors such as improving infrastructure, implementing effective dissemination actions, and defining convenient days and times for selective collection should be prioritized to sensitize and mobilize the population to participate in selective collection programs.

It is important to acknowledge that these perceptions may not be representative of the entire Brazilian territory, although they provide valuable insights. Therefore, replicating this investigation in other municipalities across Brazil, including at least one municipality from each region (North, Midwest, South, and Southeast), can help create a comprehensive understanding of the factors that drive and restrict popular participation

in selective collection programs. Such replications can also shed light on how these factors may vary and influence population adherence to selective collection programs.

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