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DEVELOPMENT OF INDICATORS TO ASSESS THE RESILIENCE POTENTIAL OF WASTE PICKER ORGANIZATIONS: AN APPROACH IN THE LIGHT OF RESILIENCE ENGINEERING

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Dulciléia de Sousa Rocha[1], Ubirajara Aluízio de Oliveira Mattos[2], Karoline Pinheiro Frankenfeld[3].

ABSTRACT

The National Solid Waste Policy (PNRS) approved through Law No. 12,305, of August 2, 2010, established the Selective Collection (CS) as an instrument, being operationalized through the organizations (cooperatives/associations) of recyclable material collectors. In this sense, cooperatives are part of the recycling chain, subsidizing several production chains. These organizations represent a complex and dynamic system, where numerous interactions occur between its elements, which may present instabilities and the occurrence of unwanted events whose resilience can be affected. The ability to withstand the different pressures and threats must be developed in order to maintain the operability of the system under adversity. Anticipating, in the sense of mitigating or eliminating the risk/danger, brings a more resilient performance. Indicators that assess resilience potential can be a strategic tool for improving resilience. The objective of this research was to develop indicators to assess the resilience potential of waste picker organizations. To this end, the main approach was used the Delphi technique (associated with the concepts arising from resilience engineering established by Hollnagel (2012). A preliminary 33 indicators were suggested, which, after two rounds and due changes according to the method, were considered relevant and consensus was reached for a total of 21 indicators, which include the dimensions of the work, the process environment. These indicators were associated with the following skills: responding, monitoring, learning and anticipating, and the Likert scale was assigned to grade the indicators, constituting the Resilience Analysis Grid – RAG.

Keywords: Cooperatives of Recyclable Material Collectors, Resilience Indicators, Delphi Method.

[1] E-mail: dulcileia.rocha15@gmail.com
[2] Email: ubirajaraaluizio@yahoo.com.br
[3] E-mail: karoline.frankenfeld@gmail.com

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INTRODUCTION

The inefficiency in waste management in Brazilian municipalities is still a problem, since its inadequate management can bring undesired consequences to the environment and the health of the population (Moura *et al*., 2018), whose solution is not trivial. It follows that there are many regional specificities, which makes it difficult for the states to promote integration and planning relevant to the management of solid waste in metropolitan regions (Silva; De Martini, 2021), with a focus on the control and inspection of generating activities, in addition to developing viable solutions.

The National Solid Waste Policy (PNRS) approved by Law No. 12,305 of August 2, 2010 and regulated by Decree No. 7,404 in 2010 (Brasil, 2010), defines guidelines, principles, objectives and instruments related to solid waste. The concepts of generator and shared responsibility are highlighted here, earning society, public and private power, merchants and others their co-participation, as well as among the principles, prevention and precaution stand out. And, in this context, the PNRS establishes the Selective Collection (CS) as an instrument, being operationalized through the organizations of recyclable material collectors (BRASIL, 2010).

Cooperatives are part of the recycling chain, as a weak link, but of fundamental relevance for the operation of the sector. Prior to the enactment of the PNRS, waste pickers already had a prominent role in both selective collection and the recycling industry (Teodosio *et al*., 2016). The fact is that the generation of waste has brought socio-environmental issues, which involve the government and society within the capitalist system where a mode of production based on consumerism prevails (Dutra, 2021), and at the same time, the performance of recyclable material collectors helps to mitigate environmental degradation, while subsidizing recycling through the various production chains (Jacobi; Besen, 2006).

In general, these projects welcome people in vulnerable situations (Coelho, 2016; Ferreira *et al*., 2016) who lack economic and social perspectives that meet the demands essential to survival. For Silva (2017), in this context, individuals can be considered who, due to the restrictions of alternatives, are inserted in the activity of waste picking, as it is the most viable within the dynamics of the labor market.

Recognized as subjects of a scenario in which social exclusion prevails, in order to face adversity, the association of this contingent in solidarity enterprises is justified as a strategic movement in favor of the collectivity, in the sense of strengthening, recognition and

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political representativeness, including (Mattos *et al*, 2021). In the sphere of solidarity economy, these associative economic enterprises are essentially focused on people, in terms of meeting the objectives of the social group and not just returning capital (Silva, 2017).

However, for the maintenance and sustainability of the enterprise, it is necessary to have an adequate financial return to the activity. Thus, it is essential to have a management capable of managing the different resources in the most efficient way in order to obtain the best results in terms of productivity and decent income, as well as safe working conditions. Campos (2014) observed in his studies within the field of recycling that waste pickers' organizations work in a precarious way and in unhealthy conditions, making the sustainability of the group unstable.

In this perspective, exercising a culture of occupational safety through management based on prevention minimizes the occurrence of occupational risks that may be present in the work environment and that have the possibility of causing harm to the worker. For this reason, the perception of risk is fundamental, since this is fundamental for survival, according to Cardozo (2009). Cooperatives represent a complex and dynamic system, where numerous interactions occur between their elements, which may present instabilities and the occurrence of adverse events whose resilience can be affected (Frankenfeld *et al*., 2023).

The productive tasks essential to the formation of the final product are generally carried out in warehouses, whose structure and infrastructure are deficient in terms of safety for the worker. They often have inadequate facilities, physical arrangements and furniture (Rocha, 2015), which implicitly bring risks. There was a lack of studies related to the issue of resilience pertinent to waste pickers and their respective enterprises. From this perspective, this article sought to develop indicators to assess the resilience potential of organizations of waste pickers. To this end, the main approach was used the Delphi technique (associated with the concepts arising from resilience engineering established by Hollnagel (2012).

THEORETICAL FRAMEWORK

SEPARATE COLLECTION & RECYCLING

The National Solid Waste Policy (PNRS), Law No. 12,305/2010, is part of the legislative framework inherent to solid waste management and complements other laws of

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the same nature. The PNRS is recognized as the legal framework for solid waste; In this way, it establishes the principles, objectives, instruments and guidelines for the integrated management of solid waste, including hazardous waste. Radioactive waste, which has its own legislation, does not apply to this Law. In chapter 2 of the aforementioned Law, selective collection is defined as "collection of solid waste previously segregated according to its constitution or composition". In chapter 3 of the same Law, selective collection is established as an instrument, along with reverse logistics for the implementation of shared responsibility for the life cycle of products.

Selective collection (CS) consists of collecting, separating, transporting, packaging and, sometimes, processing solid waste with market value for reuse or recycling (IPEA, 2013). The SC must be implemented by the municipalities, in order to meet the principle of hierarchy in waste management, through specific actions (Rocha, 2015). Priority is given to collecting waste, keeping its characteristics intact for later treatment, enabling recycling, that is, separating dry materials into categories, to be sent for use by the processing industry. According to the Panorama of Basic Sanitation in Brazil (SNIS, 2021), it is estimated that 1.07 million tons of materials were recovered, which is equivalent to 5.4% of the mass of dry recyclables potentially existing in the total mass of waste collected in the country.

The practice of selective collection has gained recognition and is increasingly present in many municipalities, it is relevant in the promotion of environmental education, aimed at reducing consumption and waste, and the incorrect disposal of waste. According to data from the Thematic Diagnosis of Urban Solid Waste Management (SNIS 2021), door-to-door selective collection in Brazil serves 69.7 million inhabitants.

Recycling is popularly understood as the reuse of something. In this case, reuse of solid waste. Rocha (2003) explains that it is the partial or total reintroduction of waste as a raw material in the production cycle, such as the pulp and paper industry, metalmechanics and glass. It is possible to understand the dynamics of the recycling chain through the Flowchart in Figure 1 below.

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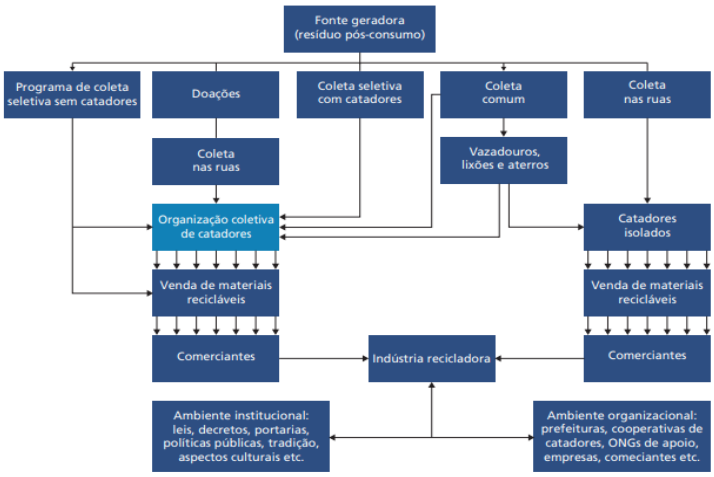
Figure 1 = Recycling Value Chain Flowchart



Source: IPEA (2011)

There is both the economic benefit arising from the recycling activity and the environmental benefit, which is so important to the environmental issue on a global scale. The advantages can be verified in different dimensions (IPEA, 2013).

WASTE PICKERS' COOPERATIVES AS A COMPLEX SYSTEM AND THE ASSOCIATED OCCUPATIONAL RISKS

Inserted in a scenario of great social inequalities, with the prevalence of the capitalist system of production, the activity of scavenging emerges as an alternative to socio-environmental externalities (Magalhães, 2012). The waste acquires a differentiated connotation, and consolidates itself as an article whose value can be resignified and thus be sold, reverting into income for a class of excluded from the capitalist system in force.

The interference of the National Movement of Waste Pickers (MNCR) in the process of struggle and recognition of the role of waste pickers, especially for their inclusion in a national policy, made all the difference for these workers. An example of this action was the inclusion in the Brazilian Classification of Occupations (CBO), through Federal Ordinance No. 397 of the MTE, published on October 9, 2002 for use throughout the national territory, of the profession of "recyclable material collector", with code 5192-5 (BRASIL, 2002).

Waste pickers' organizations emerged as a strategy for strengthening, empowerment and belonging, within an excluding context permeated with vulnerability and challenges. Federal Law No. 12,690 of 2012, which discusses the organization and operation of Labor Cooperatives, aims to ensure the professional activities of the workers involved. Therefore, in Article 2 of this Law, the following Labor Cooperatives are considered:

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The society constituted by workers to carry out their work or professional activities with common benefit, autonomy and self-management to obtain better qualification, income, socioeconomic situation and general working conditions (BRASIL, 2012).

The National Sanitation Information System (SNIS) computed the existence of 1677 waste pickers' organizations (SNIS, 2020), informed by municipal managers. However, this number may have changed due to the various circumstances existing since the event of the Pandemic (Covid-19) until then. According to the same survey, the Southeast region had the highest percentage (45%) of organizations.

The cooperative has its own statute that guides it by cooperative principles: a) Voluntary and free membership; b) Democratic and free management; c) Economic participation of members; d) Autonomy and independence; e) Education, training and information; f) Intercooperation and g) Interest in the community (Stefano; Zampier, 2006). These principles characterize labor relations different from those established in the Consolidation of Labor Laws (Machado *et a.l*, 2006), configuring an organizational model with peculiarities in terms of policies, strategies and productivity, where the collective work and collective work prevail (Rufino, 2002).

Every system has its specificities and unique functioning. By considering waste pickers' organizations as a system, which involves several elements and constant interactions, it is necessary to account for the risks associated with the complexity of this system, its factors and variables. For Ruppenthal (p. 15, 2013), "the activities inherent to human beings, since the beginning, are intrinsically linked to a potential for risk". It is known that in cooperatives the individual is exposed to the risks intrinsic to the environment, the process and the waste. The fact is that this exposure can cause damage to the physical integrity (injury) or health (disease) of the worker. Studies have already collected data that have shown the incidence of musculoskeletal diseases, injuries by accident, as well as exposure to infectious agents, heavy metals and chemical substances (Gouveia, 2012). The injuries generated in general are due to non-use of personal protective equipment (Ferreira *et al.*; Galon; Marziale, 2016).

Protecting the integrity and health of the worker is fundamental, especially in the work environment of cooperatives, where there are local factors that can affect the resilience of the group, influencing its sustainability. The ability to withstand different pressures and threats must be developed and improved in order to maintain the stability of the organization, even in situations where adverse events occur. Anticipating, in the sense

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of mitigating or eliminating the risk/danger, brings a more resilient performance, without consequences, or with less harmful consequences.

RESILIENCE ENGINEERING - A NEW PARADIGM

Oliveira *et al* (2008) deal with the word resilience, which, according to the authors, originates from the Latin *resilo* and refers to the ability to return to the previous state. The exact sciences, such as Physics and Engineering, initially appropriated this concept to refer to the elastic capacity of a physical body to return to its normal state after being subjected to some type of pressure (Barlach; Limongi-França & Malvezzi, 2008).

The concept of resilience over the years has been expanded and admitted in different areas and knowledge. However, they have always maintained similarity with the initial meaning, which concerned the capacity/ability to recover and reestablish after a "disturbance" of the original state. Some studies marked the beginning of studies on people's resilience in the organizational environment (Weick; Sutcliffe, 2001), organizational resilience (Burnard; Bhamra, 2011; HollnageL, 2012), resilience in the field of psychology (Yunes; Szymanski, 2005) and several others.

Resilience Engineering (RE) can be considered a new paradigm of Occupational Safety Engineering (EST), because, more than promoting safe work using a logic based on a culture of prevention, such as EST, RE brings propositions based on premises focused on dealing with criticalities within sociotechnical systems (Frankenfeld; Mattos, 2023), covering technical aspects of the organizational structure, people and processes, and their interrelationships. In this sense, Hollnagel *et al.* (2012) consider it relevant to have flexibility to deal with criticalities, which is an intrinsic attribute of Resilient Systems (SR), as it deals with reality, anticipating potential in order to deal with vulnerabilities and their effects, in addition to learning from positive and negative occurrences.

Systems can present complexities, and these are inherent to the specificities of each one. They are permeated by uncertainties and risk factors that make them vulnerable to disturbances and the occurrence of unwanted events that lead to accidents (Hollnagel, 2008). Developing specific skills (learning, monitoring, responding, anticipating) (Hollnagel, 2015) will increase the potential for resilience with improved performance. In this way, through indicators about the potential for resilience, it is possible to assess the adaptive capacity and response to threats/disturbances and adopt improvement actions.

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The construction of indicators must guarantee their ability to represent what is being studied. In Kligerman's (2007) understanding, indicators were developed due to the need to treat information in its original form in order to make it accessible. Monteiro and Falsarella (2007), in turn, state that indicators allow us to understand complex phenomena, transforming them into quantifiable ones to be analyzed, understood and transmitted.

Camargo (2000) states that it is essential that the set of proposed indicators has the property of expressing credibility and Mendonça (2008) completes by agreeing that the construction of indicators to assess the resilience of the system begins with the understanding of organizational activities. For the process of constructing the indicators, the Delphi Method was chosen, which is widely used in research in various areas of knowledge, as it has great potential as an investigation technique (Facione, 1990). The methodology makes it possible to compile a set of opinions from experts, geographically distant and is recommended especially when there is unavailability of quantitative or historical data. Some authors consider it as an effective method for exploratory approaches; especially in environments with great variability, Wright (2000).

METHODOLOGY

SCOPE OF RESEARCH

This research is classified as applied, exploratory, quantitative, and qualitative It was approved by the Research Ethics Committee - CAAE 49263321.5.0000.5282 with Opinion No. 4.942.176 in August 2021 and was conducted in accordance with the required ethical standards, including the signature of the ICF. This research worked with 2 distinct groups of participants (waste pickers and specialists), according to each step established to achieve the general objective.

Participating organizations and Study area

The participating organizations were selected through a *web* search, obtaining a list of organizations (cooperatives/associations) of recyclable material collectors, on the Recicloteca website (2020). Some criteria were established: **a**) location; **b**) formalization; **c**) time of work and **d**) accepted to participate in the study. In due course, an initial contact was made by e-mail to invite us to participate in the study. The acceptance was signed by signing the Term of Consent. The organizations participating in the study are located in the Metropolitan Region of Rio de Janeiro, in the neighborhoods of Maria da Graça, Brás de

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Pina and in the municipality of Mesquita. The research had three main stages, as shown in Chart 1.

Chart 1 – Research stages

Literature search	Field research	Elaboration of indicators
Objective		
Constructing theoretical framework	Observe the work environment, understand the work process and interactions (individual-environment-local factors)	Build indicators to assess the resilience potential of waste pickers' cooperatives
Description		
Database: • *Google Scholar*, CAPES Journals, SCOPUS Descriptors • Cooperative waste pickers resilience engineering, indicators	Personal notes, photographic record and appreciation of documents	Selection - Delphi Method (2 rounds) • Instrument: Questionnaire Elaboration – Resilience Engineering • *Likert*

Source: The Authors, 2022.

SELECTION OF INDICATORS TO ASSESS THE RESILIENCE POTENTIAL OF RECYCLABLE MATERIAL COLLECTORS' COOPERATIVES - DELPHI METHOD

The Delphi technique was created in the 1950s by two mathematicians at the time of the Cold War to predict the impact of technology on the world. This technique is based on a certain subject, which is dealt with by a group of experts. The technique occurs in "rounds", so that there is improvement in each round, with the purpose of a consensus or stability in the answers. It is carried out through the application of questionnaires in successive rounds, to be answered individually and anonymously (WRIGHT; GIOVINAZZO, 2006).

The selection of possible indicators to compose the initial set proposed was made based on the literature review and field research, focusing on the aspects of safety and health of the worker, on the risk factors observed. The Delphi method was chosen, (Ahmad; Wong, 2019 & Billings *et al*., 2020). Two rounds were held to choose and validate the indicators. For the formation of the group of specialists, a contact was made to make the invitation and clarify the study.

After acceptance for participation, the first round began, and the first questionnaire was sent, containing a set of 33 indicators, which covered the dimensions: a) work, b) organization, c) structure and infrastructure, d) equipment and tools, and e) individual. The experts were instructed to classify the relevance of the indicators proposed for the study, indicating: 1) relevant or 2) not relevant and according to agreement, as follows: 1) agree;

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2) partially agree and 3) disagree, with the gradations by means of the *Likert* scale (1932), in addition to the respective justifications in case of disagreement and deadline for return. To send the questionnaire, the online platform *Google Forms* was used, as it is a practical, versatile, simple to apply tool capable of generating easy-to-interpret reports for statistical analysis of the results.

After analyzing the result of the first round, feedback was given to the experts, with the sending of the second questionnaire, with the necessary adjustments and a new set of indicators, with an agreement rating according to the same scale (*Likert*: 1 to 3). The level of agreement (NC) established for approval must be ≥ 75%.

INDICATORS TO ASSESS THE RESILIENCE POTENTIAL OF WASTE PICKER ORGANIZATIONS IN THE LIGHT OF RESILIENCE ENGINEERING

After the process of selecting the indicators using the Delphi technique, the approved indicators became the *Resilience Analysis Grid (*RAG), a methodology established by Erick Hollnagel (2015) to assess the resilience potential of complex systems. The RAG is composed of the set of indicators, associated with one of the four resilience skills: (a) answering, (b) *monitoring*, (c) *anticipating* and (d) *learning*, which in turn receives a gradation (scoring system - Likert scale: from 1 to 5) for each question assigned to the indicator. As a result of this process, there are four Frameworks, to be applied in waste pickers' organizations, with the objective of assessing the potential for resilience.

RESULTS AND DISCUSSION

ORGANIZATIONS OF WASTE PICKERS

The start of operations in the organizations studied varies between the years 2003 and 2015. Each cooperative has its own way of working, with different physical arrangements, as well as a unique structure and infrastructure. In general, they occupy warehouses in peripheral neighborhoods. The main equipment are: press, scale, conveyor belt or tables (benches), mostly adapted, where the separation of the material is carried out. There are several categories of materials handled by the collectors, which arrive by trucks or carts at the sheds. The volume of material collected is disposed of in certain locations for later separation. The separated material is pressed and stored for the customer.

The collectors wear uniforms consisting of pants, blouses and boots. Regarding personal protective equipment (PPE), the use of gloves was observed by almost everyone.

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Although they stated that they wore protective goggles and ear protection, this practice was not evidenced during the study period. The collectors carry out a continuous rhythm of work, since the billing occurs by productivity.

Local risk factors were observed that permeate the work and that pose risks to the health and integrity of the waste pickers. These factors are related to the dimensions of work, the worker and the process. It is inferred that risks, such as accidents, ergonomics and biological, are present in cooperatives. Chart 2 below includes a summary of the management practiced.

Chart 2 - Summary of the internal management of the organizations studied

Internal Regiment	Quantitative	Productivity	Working hours
Self-management Collective work Meetings (ATA)	Cooperative A – 10 Cooperative B – 86 Cooperative C – 42 Cooperative D - 14	Production: variable from 20 tons/month to 240 tons/month according to size.	A, C e D: 8h/dia 2ªf to 6ªaf B: 12h x 36h 2ªf to 6ªaf

Source: Cooperatives A, B, C, and D (2022)

PROFILE OF TWO SPECIALISTS – DELPHI METHOD

The criterion for choosing the participants of the Delphi round was established based on experience and experience in the area of study (theme addressed). Professionals from public, private, academic and self-employed institutions participated, as shown in Chart 3 below.

Chart 3 - Characterization of the specialists - Delphi

Gender	Male: 9	Female: 8
Age group	25 – 35 years old	35,2%
	36 – 45 years old	47,05%
	46 – 55 years old	17,6%
Education	Environmental Engineer	17,6%
	Engineer Work.	47,05%
	Biologist	11,76%
	Environmental manager	11,76%
	Technician Sec. Trab.	11,76%
Education level	Graduation	23,52%
	Specialization	47,05%
	Masters	29,41%

Source: The Authors, 2022

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THE DELPHI METHOD ROUNDS

In the first round, the questionnaires were sent to 35 specialists, with a return rate of 65%, representing 23 responses. This first stage took place during the period from September to December 2022. The second round took place between March and June 2023 and had a return rate of 74%, that is, 17 responses (Chart 4).

Table 4 - Compilation of the questionnaires of the rounds

Round	Participants (Specialists)		
	Number of Envoys	Return	Rate of return
1st round	35	23	65%
Round 2	23	17	74%

Source: The Authors, 2023

In the first round, 33 indicators were submitted to the experts as an initial proposition, to assess the relevance and level of agreement. In the return phase of this round, the experts made 13 observations contemplating a suggestion for changing, adapting or excluding the indicator. The recommendations were analyzed, weighed, and accepted where relevant (Chart 5).

Table 5 - Result of the first round - Delphi

Indicator	1st Round		
	% agreement	% relevance	Condition
I01 - Hours worked	51,5	86,9	And
I02 - Diversity of activities	48,4	82,6	And
I03 - Rest time	72,7	86,9	And
I04 - Emergency care	84,8	100	A
I05 - Cleanliness and hygiene	72,7	100	And
I06 - Precautionary stop	87,8	100	AP
I07 - Lighting	51,5	91,3	And
I08 - Safety training	100	100	AP
I09 - Human Error	81,8	91,3	A
I10 - Incident Log	72,7	82,6	And
I11 - Continuous training	81,8	100	A
I12 - Tailings Index	72,7	78,2	And
I13 - Other occupation	51,5	82,6	And
I14 - Continuous improvement	93,9	100	AP
I15 - Availability of PPE	87,8	100	A
I16 - Signaling	87,8	82,6	A
I17 - Legal instruments	69,6	78,2	And
I18 - Risk perception	93,9	100	A

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I19 - Remuneration	72,7	91,3	And
I20 - Percentage of recyclables	75,7	73,9	MR
I21 - Safety Culture	100	100	AP
I22 - Equipment Maintenance	100	100	AP
I23 - Awareness and transparency	96,9	95,6	AP
I24 - Interpersonal relationship	87,8	82,6	A
I25 - Turnover	72,7	82,6	And
I26 - Safety Inspection	100	95,6	AP
I27 - Autonomous decision	81,8	82,6	A
I28 - Vector Control	69,9	78,2	And
I29 - Faturation	72,7	91,3	And
I30 - Number of people	72,7	82,6	And
I31 - Uptime	51,5	82,6	And
I32 - Location	45,4	73,9	And
I33 - Personal qualification	100	95,6	AP

Legend: MR – Maintained with Reservation; A - Changed; E – Excluded; I – Included; AP – Approved

The indicators: I01 - Hours worked; I02 - Diversity of activities; I03 - Rest time; I05 - Cleanliness and hygiene; I07 - Lighting; I08 - Lighting; I10 - Incident Log; I12 - Tailings index; I13 - Other occupation; I17 - Legal instruments; I19 - Remuneration; I20 - Percentage of recyclables; I25 - Turnover; I28 - Vector control; I29 - Billing; I30 - Number of people; I31 - Uptime and I32 - Location obtained an evaluation of the level of agreement below the established NC percentage and, for this reason, these indicators were eliminated and did not proceed to the second round.

On the other hand, the indicators: I08 - Safety training; I21 - Safety culture; I22 - Equipment maintenance; I26 - Security inspection; and I33 - Personal qualification reached 100% of the consensus. This result indicates that the path to an efficient and sustainable performance, from the point of view of occupational safety, is focused on a practice of the activity based on prevention and response capacity in the face of an unwanted event.

Indicators I02 - Diversity of activities and I32 - Location were the ones that received the highest number of objections, although they are considered relevant. Such objections point to little influence or relevance correlated to the object of study and the theme.

In general, all the indicators initially submitted were considered relevant, with a variation of 73.9% (I32 - Location; I20 - Percentage of recyclables) to 100% (I04 - Emergency care; I05 - Cleanliness and hygiene; I06 - Stop as a precaution; I08 - Safety training; I11 - Continuous training; I14 - Continuous improvement; I15 - Availability of PPE;

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I18 - Risk perception; I21 - Safety culture; I22 - Equipment maintenance), with the average being 89.44%.

The need to adapt some indicators was verified, in total there were seven (7), namely: I09 - Human error, became I09 - Tolerance to error; this indicator is associated with the understanding that to err is human and that error can be a consequence of the interaction of the worker with the local factors to which he is involved. I11 - Continuous training was changed to I11 - Periodicity of training; associates training routine inherent to the activity with planning. I15 - Availability of PPE changed to I15 - Safety equipment; encompasses safety attributes linked to specific equipment.

Indicator I16 - Signaling became I16 - Safety resources and devices; with a wide scope. Indicator I18 - Risk perception was changed to I18 - Risk recognition; broader character of identification and analysis of possible damages. In turn, the indicator I24 - Interpersonal relationship was changed to I24 - Peer communication; relevant for collaborative processes, for communication, learning and socializing. Finally, there was a change from the indicator I27 - Autonomous decision to I27 - Autonomy of decision; It corresponds to the ability to make decisions and act independently in the event of an unwanted event.

Subsequently, after the analysis and the necessary changes, questionnaire 2 was returned to the experts with a new set of indicators (16), for the second round (Chart 6).

Table 6 - Second round - Delphi

Indicator	Round 2	
	% agreement	Condition
I01 - Agility of action	88,2	AP
I02 - Precautionary stop	82,3	AP
I03 - Safety training	100	AP
I04 - Error tolerance	82,3	AP
I05 - Periodicity of training	100	AP
I06 - Continuous improvement	100	AP
I07 - Safety equipment	100	AP
I08 - Safety features and devices	100	AP
I09 - Recognition of risks	100	AP
I10 - Safety Culture	100	AP
I11 - Maintenance and correction	100	AP
I12 - Awareness and transparency	82,3	AP
I13 - Peer-to-peer communication	82,3	AP
I14 - Safety Inspection	100	AP

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I15 - Decision-making autonomy	82,3	AP
I16 - Personal qualification	100	AP

Source: The Authors, 2023/Caption: AP - approved

As a result of the 2nd round, it was found that there was a desired consensus for the 16 indicators and, concomitantly, the need to include five (5) more indicators was verified: I17 - Accident investigation; I18 - Construction of learning; I19 - Compliance of procedure; I20 - Redundancy and I21 - Anticipation of risks. These inclusions aimed to aggregate relevant information about the performance of complex systems from the perspective of Resilience Engineering (Chart 7).

Chart 7 - Changes made after the 2nd round

Indicator	Situation
I01 - Agility of action	Maintained
I02 - Precautionary stop	Maintained
I03 - Safety training	Maintained
I04 - Error tolerance	Maintained
I05 - Periodicity of training	Maintained
I06 - Continuous improvement	Maintained
I07 - Safety equipment	Maintained
I08 - Safety features and devices	Maintained
I09 - Recognition of risks	Maintained
I10 - Safety Culture	Maintained
I11 - Maintenance and correction	Maintained
I12 - Awareness and transparency	Maintained
I13 - Peer-to-peer communication	Maintained
I14 - Safety Inspection	Maintained
I15 - Decision-making autonomy	Maintained
I16 - Personal qualification	Maintained
I17 - Accident investigation	Included
I18 - Construction of learning	Included
I19 - Procedure Compliance	Included
I20 - Redundancy	Included
I21 - Anticipation of risks	Included

Source: The Authors, 2023/Caption: AP - approved

INDICATORS TO ASSESS THE RESILIENCE POTENTIAL OF WASTE PICKER ORGANIZATIONS – RESILIENCE ANALYSIS GRID (RAG)

The final indicators were structured according to the four (4) skills recommended by Hollnagel (2012), which, when applied according to the "Resilience Analysis Grid"

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methodology, indicate how resilient a system is, according to its resilience potential. Resilience indicators do not measure resilience itself, but potential. The following are the indicators that make up the RAG. The first Table presents the set of indicators related to the ability to respond, the second Table corresponds to the ability to monitor, the third Table refers to the ability to learn and the fourth Table is associated with the ability to anticipate (Chart 8).

Chart 8 - Resilience Analysis Grid

RAG	
Indicators	1. Ability to Respond
Staff qualification	Are people prepared to deal with accidents in the Cooperative?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Agility Action	Can you act quickly to avoid an accident, a problem, or help the person affected?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Autonomy Decision	Can you make a decision if an accident or a problem occurs?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Security features and devices	Are the equipment and machinery necessary for accident prevention or damage reduction sufficient?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Periodicity training	Are the trainings required to perform the job properly and safely carried out frequently?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Stopping as a precaution	Do you interrupt your work or anyone else's, because you understand that it is not safe?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Indicators	2. Ability to Monitor
Awareness and Transparency	Is it possible to talk about accident prevention in your work environment with your partners?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Peer-to-peer communication	Are there meetings to talk about risks, about ways to avoid accidents and communicate leaves due to work accidents?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Safety culture	How often does the Cooperative meet to talk about the activity and risks?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Maintenance and correction	Does the Cooperative carry out maintenance, renovation and inspection procedures to detect and correct failures that can cause accidents?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Error tolerance	If you notice any condition that can lead the worker to make a decision that causes an error or accident, do you notify anyone?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Indicators	3. Learning Ability
Accident investigation	Are accident analyses carried out in the Cooperative?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Construction of learning	Do workers participate in the results of accident analyses?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Continuous improvement	Are the methods for carrying out the work safely maintained and improved as needed?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Procedure Compliance	Does the Cooperative adopt any occupational safety standards?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS

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Indicators	4. Anticipation Ability
Safety equipment	Are individual or collective protective equipment (e.g., PFF masks, gloves, boots, goggles) available to workers?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Redundancy	Does the Cooperative reinforce work safety, including other safety equipment (e.g., fire extinguishers, emergency lights, useful telephones, signage?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Recognition of risks	Do you recognize the risks that exist in the workplace?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Safety inspection	Do you check if the place and conditions to carry out the activity are adequate?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Safety training	Do you receive safety training to do your job?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS
Anticipation of risks	Is the cooperative concerned with ensuring conditions (environment, tools, equipment, PPE) to avoid risks during the performance of the work?
	(1) NEVER; (2) RARELY; (3) SOMETIMES; (4) ALMOST ALWAYS; (5) ALWAYS

Source: The Authors, 2023

CONCLUSION

As for the field research, the results of the *on-site observations* demonstrated the vulnerability of the waste pickers to the risks present in the work environment. Waste pickers' organizations are complex systems, and as such they present variables and interactions between the elements, in a dynamic way. It is important to understand the parts (worker, machinery and equipment, tools, etc.) of this system (waste pickers' cooperatives) in order to understand the whole and be able to act effectively.

Regarding the selection of indicators to compose the Resilience Analysis Grid, the results showed that the Delphi method is an efficient tool for use in the process of collecting expert opinion. The technique met the objective of seeking a consensus on the indicators to assess the resilience potential of organizations of recyclable material collectors. It was possible to deepen the questions and thus work with the agreements or disagreements, in order to validate the process in question, using the multidisciplinary view of the participating specialists.

As for the general objective of the study, the indicators established proved to be adequate, as they obtained a high level of agreement. They include attributes capable of generating information relevant to the organizational resilience of recyclable material collectors' cooperatives. From its application, it will be feasible to verify situations related to the deficiency in the process within the system, which favors improving the management of safety and the management of local factors, as well as in the planning of work, increasing the resilient potential. It should be noted that the evaluation must be a planned and

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periodically repeated procedure, since it will be used in complex and dynamic systems subject to different variables.

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