DEMAND-DRIVEN DESIGN STRATEGY FOR INTER-ORGANIZATIONAL CIRCULAR SYSTEM – THE VALORIZATION OF EXPANDED POLYSTYRENE IN BRAZIL

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ABSTRACT

The valorization of plastic wastes in the Circular Economy poses the challenge of developing inter-organizational systems. Concerning the implementation, the inter-organizational level consists of a set of companies from the same segment acting in different roles in the circular system. This research aims to demonstrate a structured method designed to develop a demand-driven inter-organizational closed-loop circular system for the valorization of packaging waste.

The five-step method includes (i) Contextualization/problematization, (ii) Closed-loop system mapping, (iii) Closed-loop system consolidation, (iv) Building Commitment,(v) Pilot system implementation and operation. A real case illustrates the method. As the unit of analysis we have chosen the supply chain and reverse channels of expanded and extruded polystyrene packaging in Brazil. The project was developed from December 2021 to March 2022.

The contribution to the literature is to validate the premises and to provide insight into the challenges of developing real circular economy closed loop systems. The practical contribution is to support the development of a recycling system of packaging in a developing country.

Keywords: Circular economy, Large-scale engineering systems, Complexity, demand-driven, expanded-extruded polystyrene

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1 INTRODUCTION

The United Nations Environment Program & International Resource Panel (IRP, 2018) defines remanufacturing, reconditioning, repair, and direct reuse strategies as value-retention processes (VRPs). Although professionals should design products from the perspective of VRPs from the beginning, the current product portfolios commercialized by manufacturers in the market do not fully match these requirements. The consequence is products impact on the environment (Sastre et al., 2022) independent of the industrial segment. Therefore, on one side the managers are stressed by the challenges of designing products that do not harm the environment. CE upstream innovation requires managers to have a cultural disposition and management maturity to design in a systemic and collaborative way with different stakeholders in the chain (Jabbour et al. 2019). On the other side the pressure of legislation, public opinion, and competitiveness (Saidani et al., 2017; Pan et al., 2015) pose a sense of urgency in minimizing the impact of the products currently commercialized in the market. Hence, at the firm level, the transition to the CE also occurs through waste management approaches (Heras-Saizarbitoria et al., 2023) like the design and implementation of inter-organizational[1] closed-loop systems for valorisation of pre-consumption and post-consumption waste on an industrial symbiosis basis.

The CE butterfly diagram (EMF, 2015, p. 24) brings the recycling strategy to its outermost link in the technical cycle as a last-choice strategy, since recycling tends to consume more energy than other approaches. Despite that, we adopt the premise that the recycling strategy should not be considered a detour but a way to prepare managers to reach higher levels of collaboration among stakeholders. The design of closed loops and reverse logistics will be natural operations for recycling systems, which will be further essential in the design of innovative circular product systems. The complexity of carrying out the design of reverse logistics resides in connecting distinct organizations such as, collecting and sorting companies, recycling companies, and other public and private institutions. All of these organizations bring their managerial perception of value and requirements (IRP, 2018). It usually involves sensitive and confidential information sharing and efficient communication (Moritz and Petersen, 2022).

Assuming that recycling is also a valuable strategy for CE, the next question is how to develop, implement, manage and improve inter-organizational closed loop systems in a structured and reproducible way. The number of frameworks on CE proposed in the literature is increasing. Considering the design research field, Lieder and Rashid (2016), for instance, combined three aspects, environment, resources, and economic benefits. The authors suggest a concurrent approach. Top-down, the governmental bodies and policymakers maximize environmental benefits through strict control of industrial businesses. From the bottom-up, manufacturing companies' managers put their effort into economic benefits and growth due to competitive pressure. Moreno et al. (2016, p. 937) developed a conceptual framework linking five design strategies and five circular business model archetypes. As a result, they provide 10 recommendations when designing CE on a DfX basis. Pigosso and McAloone (2021) propose the CE readiness self-assessment tool, MATChE (MAking the Transition to a Circular Economy), following iterative cycles of theoretical development and empirical co-development with potential users. The frameworks vary their focus among strategic, tactical, and operational decisions and do not privilege the closed-loop development, since the framework was developed for a broader and strategic perspective of Circular Economy.

Regarding the literature from the supply chain field, Amir et al. (2022) proposed a framework for circular supply chain implementation by design. The authors distinguish 'closing the loop by design' from 'closing the loop by chance'. We may classify the current research as closing the loop by chance since products were not designed for multiple life cycles from the beginning, as expected in the concept of closing the loop by design. Concerning the closed loop context, we may introduce reverse logistics as one of the building blocks of CE and a key-step to facilitate value-added activities. The Ellen Macarthur Foundation’s (2016) reverse logistics maturity model (RLMM) sheds light on the challenge of developing closed-loop inter-organizational systems. The maturity model considers five levels to assess maturity across reverse logistics (front end), recovery (engine) and remarketing (back end). Such levels follow project and process management stages, widely used for continuous processes improvement. Managers can apply the model to assess organizations reverse logistics’ maturity to

[1] Regarding the context of closed loops in the Circular Economy, “the inter-organizational level consists of a set of companies from the same segment acting in different roles in the system” (WBCSD, 2018, p. 10).

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begin scaling-up their circular capabilities. The RLMM framework points as a first key-success factor realizing economies of scale. For instance, a successful new CE inter-organizational closed loop system design should incorporate recycling companies that have consolidated target audiences to their recycled goods, ensuring a pulled demand to the nascent closed loop system (Paula et al., 2021). It is recommended to guarantee the recycled product demand every time we valorise a material and return it to the market. Recycled products must not be stuck on shelves and warehouses, with the risk of converting in another residue.

Hence, some premises guide this investigation (i) recycling may be a valid strategy to reduce the impact of products not designed with the perspective of Circular Economy from the beginning (Heras-Saizarbitoria et al., 2023); (ii) designing reverse logistics closed loops for recycling purposes is a way of developing the culture for collaboration in CE (Moritz and Petersen, 2022); (iii) it is adequate to design the circular closed loop assuring economy of scales via demand-driven and other approaches, (iv) it is necessary to design with failure in mind, it is better to test and prototype early as many times as possible (Moreno et al.,2016); (v) the design with 'hands-on' fosters a call for action and accelerates the knowledge gain (Moreno et al., 2016). The research question which arises is how to operationalize these premises in a method to design an inter-organizational closed-loop system for recycling of goods? This research aims to demonstrate a structured method designed to develop a demand-driven inter-organizational closed-loop circular system for the valorisation of packaging waste. The contribution to the literature is to validate the premises and to provide insight into the challenges of developing real circular economy closed loop systems. The practical contribution is to support the development of a recycling system of packaging in a developing country. The remainder of the paper is structured as follows: section 3 defines the case study and the methodology. Sections 4 and 5 present results and practical implications, respectively. Section 6 provides final considerations.

2 CASE CONTEXT DESCRIPTION

The Center for Intelligence in Projects and Systems (NIProS) is a research group at the Federal University of Rio Grande do Sul. The NIProS team has become a partner of a local startup that provides waste management services, named in this paper as STup. The cooperation between NIProS and STup is characterized by mutual benefits. NIProS researchers apply industrial engineering tools and methods to design innovative solutions to the complexities of implementing circular systems and reverse logistics. STup implements, operates, and evaluates the systems designed by NIProS via pivoting cycles. This partnership provides methodology, the hands-on and the prototyping elements mentioned before.

STup was contracted by a large Brazilian company that is a reference in online delivery, named in this paper as ODc, to manage waste from its operations. ODc holds over 80% market share of the food delivery sector in Brazil. Nevertheless, Law No. 12,305 of August 2nd, 2010 - National Solid Waste Policy (PNRS) (Brasil, 2010) instituted Reverse Logistics (RL) as the entire process of operations related to the reuse and disposal of materials, waste, and products in general. Special attention is paid to the shared responsibility of waste producers and amends Act No. 9.605 on Criminal Penalties relating to behavior and activities harmful to the environment.

ODc contracted the partners NIProS-STup to develop the Reverse Logistics and recycling of Expanded and Extruded Polystyrene (EPS/XPS) packaging in Brazil. The EPS/XPS brand's name is Isopor® or Styrofoam. From a production of 100 thousand tons of styrofoam/year only 34.5 tons are recycled in Brazil. Durable goods use part of the material but most of the amount is not recycled because only 7% of Brazilians know that Isopor is a recyclable material.

Polystyrene (PS) is the chemical substance in styrofoam which may present two different physical characteristics, depending on the preparation technique. The expanded styrofoam (XPS) shows a brilliant surface and it is used in food trays and packs. The extruded styrofoam (EPS) shows the inner polystyrene pearls on its surface and it is used in the structure of thermic boxes, civil construction and other applications. The partners of ODc are responsible for delivering food in EPS and XPS packaging that are discarded by the population, collected by the municipal collection service and displayed in landfills. Although the ODc managers are not directly responsible for the packaging their partners use in the meals, they have decided to proactively develop a strategy of lowering the amount of packaging of their delivery services by 2025, including EPS/XPS.

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3 THE METHOD

NIProS has developed a five step method, tested before in other inter-organizational circular systems contexts, described next.

Step (i) Contextualization/problematization - aimed to investigate the characteristics of the residue, identify the logistical difficulties, elucidate the amount of waste generated, understand the level of technology available, comprehend the material recyclability, and the possibility of increasing its market value. These topics were the main subjects of 24 interviews with companies' collaborators and sorting cooperatives members involved in the recycling chain. The interviewers were the following: (9) producers/processors; (5) cooperatives; (1) consolidator; (1) beneficiary; (3) plastic associations; (2) environmental education projects; (1) start up; and (2) recycler organizations.

Step (ii) Closed-loop system mapping - aimed to design a theoretical operational structure for the inter-organizational circular system of expanded polystyrene in the territory (Brazil). The data collected in step (i) served as the basis for step (ii).

Step (iii) Closed-loop system consolidation - considering the hands-on approach and early prototyping, we identified possible organizations that could play a role in EPS/XPS recycling chain in Brazil, using internet sites and the interview data as sources of potential partners. The roles were inspired in the reverse logistics solution of Ellen Macarthur Foundation (2016, p. 7), including ODc manager (systems investor); STup manager (systems governance and operation); Recycler Company named Rb, Consolidator company from Midwest Brazil (gathers material from 21 smaller sorting cooperatives) and waste collector and sorting cooperatives from south Brazil (sorts material). Our premise at the beginning of a new inter-organizational circular system consists in incorporating inside the closed loop system players that commercialize high-value-added products made with recycled material, which are already recognized by the market and consumed in large volumes. The players for each reverse flow operation were defined and invited to participate in the pilot project considering the following selection criteria: companies that were former partners from STup, that were willing to participate and give access to performance data; strategic location in logistic terms; present some level of management maturity that facilitates pilot implementation. This step also involved the creation of 4 scenarios for the pilot system, considering the role of the client company and the initial scale of the project.

Step (iv) Building Commitment - this step aims to raise awareness and build commitment via workshops. The workshop's central theme was “How to increase the volume and quality of EPS/XPS for recycling?” and as sub-themes (i) needs and perceptions of value among the players, (ii) arguments for project communication to stakeholders, (iii) risks, and barriers identification. We invited 35 members who formerly accepted to participate in the pilot inter-organizational circular system for EPS/XPS waste. The group included 10 members from ODc (sponsor, marketing, consumer communication, sustainability, legislation affairs), 6 members from STup (leadership, operations, consumer communication, project team); 6 members of NIProS (leadership and team), 6 members of the Recycler Company Rb (leadership, operations), 3 members of Consolidator company, 2 members of Waste collector and sorting company in South Brazil, 2 members of the Public Ministry (Midwest and South Brazil). The workshop objectives were: Validation of insights and hypotheses raised in the mapping phase; Presentation and validation of the proposed network for the pilot; Identification of potential difficulties and opportunities not yet mapped; Definition of metrics for each player; Alignments for pilot project starting. The workshop members have evaluated the event quality via Google Forms®.

Step (v) Pilot system implementation and operation - in this stage it is necessary to stablish a structure for the system's governance. STup was responsible for implementing and operating the closed loop system in practice under the supervision of ODc management. The NIProS-STup teams defined KPIs. The pilot project ran from December 2021 through March 2022. The ODc’s sponsor made the follow-up of deliverables weekly. We have used as repository and management tools the Monday®, Schedule platform, Google Drive®, and the Miro® platform. A final interview was performed with STup members to evaluate the benefits of the partnership with NIProS to design the pilot circular project stage.

4 RESULTS

As mentioned in section 3, a first finding from **step 1** was the recyclability of Polystyrene (PS), the building material of EPS/XPS. The XPS (Extruded Polystyrene) is produced through an extrusion process and the surface is brilliant and homogeneous. XPS is widely used in food trays (Figure 1a).

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The EPS (Expanded Polystyrene) is produced from small flakes of Polystyrene that undergo an expansion process (using pentane gas) and is use in civil construction. It is 98% composed of gases and the inner pearls are visible on the surface (Figure 1b). The large volume of the materials and their low density, represents high logistics costs in transportation. Therefore, the EPS/XPS degassing process is essential to reduce the material volume before transportation and they gain more market value if their surface is clean, free of oil and other detritus. The recycling process is similar for both materials and they are considered 100% recyclable.

Figure 1a. XPS chicken tray and sandwich box

Figure 1b. EPS plates

The technical visits to waste collection companies revealed a predominant weak technological infrastructure, manual sorting of the materials and large presses for material compression. Other relevant findings from step one included, (i) the identification of actors in the chain; (ii) the understanding of the materials market prices at each step of the process; (iii) the identification of technologies, equipment used in the recycling chain, and suppliers as well; and (iv) the identification of recycle products marketed nowadays. The analysis of the interviews was the enabler to the design of the EPS supply chain from Figure 2, comprising the method's **second step**. This step resulted in the identification and documentation of the current manufacturing chain of EPS/XPS in Brazil. The direct and reverse supply chain operates as follows. The (i) Polymer Manufacturer, chemical industry - makes polymer PS, and the EPS/XPS (pearls); the (ii) Product manufacturer, transforms Polystyrene (PS) via expansion with pentane gas to generate EPS, or by extrusion and butane gas to generate XPS; these players also convert these raw-materials in packaging, food trays, boxes and other objects; the (iii) Waste Collector and Sorter company, collects and sorts post-consume material from households and large generators. This company separates EPS/XPS from other materials before pressing, degassing, or pelletizing the material; (iv) Consolidator company, gathers larger volumes of material processed by waste collector and sorter companies and proceeds the degassing process; (v) the Recycler, uses post-processed EPS/XPS waste and transforms it into a new product. Frequently the recyclers valorize the EPS/XPS waste by developing products for civil construction like baseboards and ceiling lining boards. The (vi) large Waste generators are home appliance suppliers and similar companies that discard styrofoam used as equipment protection.

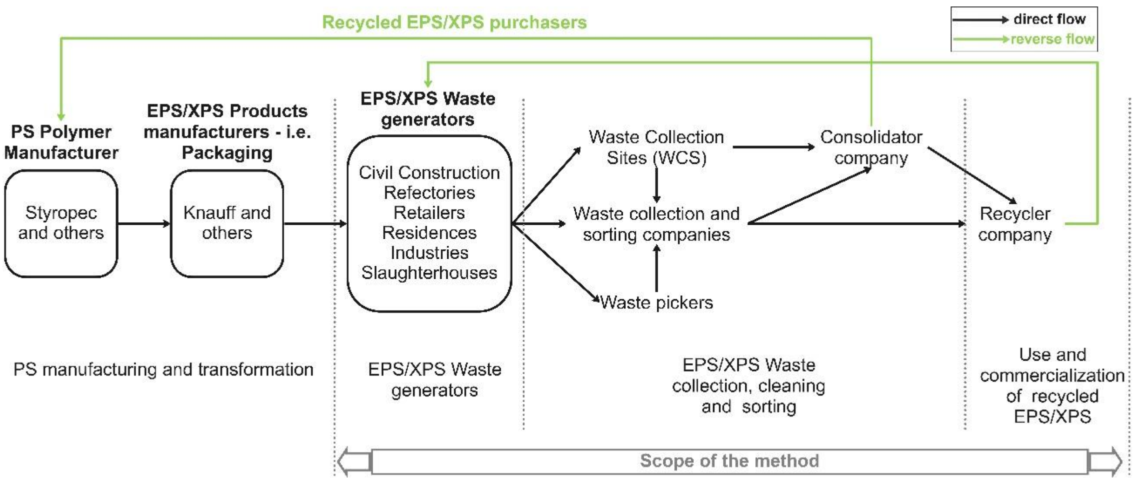

Figure 2. Main players in the Brazilian EPS supply chain direct and reverse flows

Ellen Macarthur reverse logistics maturity model (EMF, 2016) considers a key success factor for gains of scale the outsourcing of returned products to recycling providers. Interviews revealed that 2 large recyclers were already investing in the development of reverse logistics for EPS/XPS in different

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regions of Brazil. Company recycler A (Ra) accepted only very clean material from large generators, while recycler B (Rb) accepted greasy material from food post-consumption. Moreover, Rb is located in middle-south Brazil with a good logistics position to other regions in the country. The Rb managers' strategy was the installation of degassing equipment in waste collector companies of any region for free, with the condition that collectors sorted and degassed 3 to 5 ton EPS/XPS per month. At the time of investigation, the production of civil construction components with recycled EPS/XPS at Rb was much below the processing capacity of the company, and their products were highly demanded by the market. These characteristics made Rb a very good candidate to be part of an inter-organizational system for EPS/XPS in Brazil. The high demand for Rb recycled products resembles demand-driven manufacturing, where production is based on actual customer orders (demand) rather than a forecast.

Step 3 started with the goal and scenarios for the pilot project. The goal was to reinforce the existing recycling chain and to establish cooperation between the players ODc, as an investor of the recycling chain, STup as the operator, and Rb as the recycler, consumer of the EPS/XPS discarded by large generators and population. The NIProS/STup team created four scenarios for the pilot process, as demonstrated in Table 1.

Table 1. Scenarios for a pilot inter-organizational circular system for valorisation of EPS/XPS packaging waste

Scale	Lower technology level	Higher technology level
Local Scale	**Scenario 1** Individual small or midsize cooperative, sorting, pressing and balling the material. Challenge is to increase volume in the cooperative.	**Scenario 3** Individual, large cooperative, sorting and degassing and/or pelletizing. Higher degree of technology, cooperative commercializes more value added material with players of the chain.
Regional Scale	**Scenario 2** Consolidation from a network of cooperatives that sort and press the material. Creation of a commercialization network, where the consolidator collects material from the cooperatives and processes it by densification or pressing for later shipment to other players.	**Scenario 4** Network of cooperatives, with degassing and/or pelletizing technology. Creation of processing networks in strategic points of the country, with large cooperatives with a higher degree of technology, that commercializes more value added material with players of the chain.

The scenarios reveal hypotheses that would be under test. Scenario 1 comprises low technology and local action operation with limited quantity of EPS/XPS only pressed for transportation. Scenario 2 consists of a regional Consolidator degassing larger quantities of EPS/XPS gathered from additional waste and sorting companies in the surroundings of it. Scenario 3 involves the single waste local company degassing EPS/XPS with larger operation capacity. Scenario 4 concerns a Consolidator company pelletizing larger quantities of EPS/XPS, gathered from other companies. The last scenario includes the pelletizing technology that adds value to the recycle EPS/XPS and extra gain of scale of transportation, due to density increase to the material. All the scenarios include material collection>sorting>hydraulic pressing>degassing>recycling operations. The logistics should be operated between each stage by STup, taking the material from one company to another. We operated the scenarios in different regions of the country for cost testing purposes. The ODc managers approved the more interesting scenarios for implementation as described. They discarded scenario 2 as it depended on the acquisition of expensive equipment. Thus, after analyzing the opportunities, the ODc managers agreed that the pilot project implementation should occur through scenarios 1, 3 and 4. The first should be implemented in an individual cooperative in the South of Brazil, without degassing operation. The cooperative at scenario 1 is located in a city with urban collection performed by a private service that maintains close communication with the population. The hypothesis was that this communication would facilitate the increase of material discarded correctly by the population. Scenario 4 consisted of a consolidating cooperative, which is connected with 21 cooperatives, located in Midwest Brazil with experience in degassing EPS/XPS. Scenario 3 would take place at the STup operations space, in south Brazil, which would work as a consolidator and perform the material pelletization. Thereafter, the partners were invited to participate in an alignment workshop. The team developed a business model canvas and defined KPIs focused on results expected for each scenario. The last activity was the proposition of a governance structure with the ODc managers and investors acting as the leaders.

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Step 4 consisted in the alignment workshop. NIProS-STup team developed the workshop remotely because of pandemic isolation and due to the distant geographical location of the participants. They used the ZOOM® platform to hold the event and the MIRO® platform (www.miro.com) for collaborative activities among the members. The workshop lasted 4 hours with the following activities, a brief formal opening by ODc and NIProS-STup leaderships. Next, all participating members made a short presentation of the organizations' business operations. The workshop organizers performed a language unification, followed by the EPS/XPS waste chain presentation, for validation purposes. After a 15 minute break, the organizers divided the 35 participants into 2 mixed groups to make the analysis: "How to increase the volume and quality of the material". The members presented results in the large group after 1 hour. The last activity was the analysis of "Risks and barriers" using the qualitative Probability x Impact matrix (PMI, 2017). After the groups' presentations and free manifestation, STup presented the governance structure and the schedule of further steps of the pilot operation implementation as final words. The members proposed realistic recommendations to (i) increase the volume of material collected, (ii) to increase the quality of the material collected, and (iii) to increase both volume and quality. The NIProS-STup team categorized the recommendations in technical, labor, equipment, innovation, logistics, collection, institutional, material, generator's education, and taxes.

Concerning the 20 recommendations for the volume increase classification, the category "Equipment" was the smallest with 6 items. This finding suggests an opportunity for improving the quantity of material processed by giving more access to degassing and other equipment and/or optimizing their use by the cooperatives. The group "Material" (7 items) included suggestions for eliminating EPS/XPS residual contamination. Inside the group of recommendations for increasing volume and quality, the "Collection" (5 items) category included opportunities of gathering material from large generators. It is valid to mention that the players reinforced the population education as mandatory for pilot project success. The analysis of risks and barriers resulted in 34 risks listed during the workshop. From these, the team classified 29 as high risk, with 9 receiving the maximum score on the risk scale (0.72). The predominance of high probability and impact risks occurred in the "bureaucratic" and "tax" categories, such as: the fact that the recycling units are not insured, there is a lack of information about recyclability, the urban collection truck is unable to go to some regions of the cities. The governance members should monitor the risks throughout the pilot implementation, with the aim of reducing the chances of occurrence of problematic incidences. The team considered that the risk analysis would be useful to guide the review of the hypotheses to be tested at the time of implementation and the review of the metrics that will be measured. All participants received an event evaluation form with the following topics: quality of communication prior to the workshop, workshop contents and activities, coordination and technologies used. The answers were given on a scale from 1 to 5, in which the value 1 means "did not meet expectations" and 5, "exceeded expectations". The return rate was 33%, of which 30% rated 4 for all items, and 70% rated 5 for all items.

In step 5, the pilot circular system implementation is expected to last 3 to 6 months. STup and ODc will create a communication plan to explain to the population and generators details on cleaning EPS/XPS materials before discarding. STup will be responsible for the operation of the pilot project in 3 different cities (2 cities in the South and 1 in Midwest Brazil). ODc will hold meetings with STup to monitor the pilot project, participate in follow-up meetings with all players and make technical visits. STup will plan and coordinate the follow-up meetings with the Consolidator and the Waste collector company, make the analysis of project KPIs, and organize meetings. The players will receive support from STup management, collect and share information on operations and KPIs. They will also participate in recurrent meetings. NIProS will conclude the project reports and wait for future demands.

5 DISCUSSION AND PRACTICAL IMPLICATIONS

The five-step method was effective in designing strategies for operating the reverse flow of EPS/XPS and the valorisation of the material by a recycling company (Figure 2) as a starting point for hypothesis evaluations. Nevertheless, we highlight some aspects that may have contributed to its implementation and demonstrated to be relevant in applications of a similar nature.

Top Down and bottom up pressure - The case studied would fit the first archetype from the RLMM model of "Low value extended producer responsibility" (EMF, 2016). Despite the Brazilian PNRS law, the EPS/XPS manufacturers and packaging industry do not perform a fully extended producer

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responsibility, but some limited projects around the country. On the other hand, ODc started the process because its brand would be jeopardized by the impact on the environment caused by the EPS/XPS packaging of its business partners. In this case, ODc is a large empowered organization leading the project. We observed both the top-down and bottom-up motivation of Lieder and Rashid's (2016) framework. The PNRS act from the Brazilian Government placed pressure on ODc to reduce the impact of its service, even though the company was not directly responsible for the packaging used by its partner restaurants. The ODc decision was strategic to maintain its leadership in the market and a good image of the brand.

Collaboration, Trust and Knowledge sharing - The partnership between NIProS and STup created a synergy between methodology and practice. NIProS is a research group with access to academic literature, knowledge of management, and decision-making tools available in industrial engineering. STup has accumulated expertise in successfully operating waste management projects for large companies in different regions of Brazil. In the words of the STup manager "[...]NIProS gives solidity to the work that we do. The entire theoretical consulting, analytical, and research framework that NIProS develops is extremely complementary to everything STup does. So when we work together we can build trustable solutions. [...] Research provides the foundation we need, especially in an environment that is still very uncertain (innovative)." Moreover, former experiences between these institutions have proven a shared culture and a common understanding in the accomplishment of shared tasks and outcomes. These elements are essential to collaboration effort, as mentioned in Moritz and Petersen (2022).

Scales and Demand-drive system - Still regarding the scope of this method it reflects the Resource Value archetype from Moreno's et al. (2016) framework. An important premise lies under this kind of circular business model. It is necessary to have a production pulled by a product that is already successful in sales in the market. Otherwise, there is a risk of stocks of unsold products becoming the new residue impacting the environment. Bearing that in mind, the 100% recyclability of PS was great news. Interviews with manufacturers demonstrated their great interest in bringing the post-consume material back to the system and the low taxes of loss in recycling. Moreover, there was a large-scale demand force pulling the whole circular system. We have decided to keep Recycler Rb in the pilot project firstly because this company added more value to the EPS/XPS waste material than Recycler Ra. The civil construction product fabricated by Rb with recycled EPS/XPS is the principal consumer of the residue. Moreover, the PS manufacturer would also consume degassed and pelletized PS as a charge for new polymer manufacturing. Consequently, both chains would pull tons of post-consume EPS/XPS in the country.

Leveraging existing capacity - This study revealed the existence of two organizations already striving to organize by themselves the reverse logistics of EPS/XPS in Brazil, intending to increase the volume of material as input for their specific operations. Interviews revealed that there was an idle capacity in the recycling processes of both organizations and they had made contact with cooperatives with the aim of negotiation of EPS/XPS. These facts may have accelerated the rate of implementation of the pilot system because some players were formerly integrated and had already established trust in their relationships. We observed a similar situation when deciding the players for scenarios. The former relationships of STup and cooperatives in the country were mandatory for a decision structured on confidence and the technological capacity of the players.

Relations established on a Win-Win basis - Interviews with Waste collectors and sorting companies revealed them as the weakest link in the chain. The risks mentioned in the workshop reinforced the low technological capacity of cooperatives. In addition, the managers of these companies are frequently vulnerable people that depend on the municipal governments to support the company's operations. ODc and Rb managers demonstrated their interest in supporting these players providing degassing equipment, managerial support and training to improve capacity. STup was in charge of implementing changes in cooperatives.

Alignment of expectations and commitment - The workshop was useful to validate the design of the pilot circular system and to reinforce the notion that the design of quality into the reverse flows depends on all players' cooperation. The common view of the system brings valorisation of each role in the system and commitment. The team presented the values of Circular Economy at the workshop's beginning and the win-win perspective as the basis for operations and trust. STup considers the alignment of values and expectations a key-element in the five-step methodology and mandatory before the system implementation. The collaborative risk analysis allowed all players to express the elements that brought them concern. Some riskier elements were repeated by more than one player and should be the target of mitigation efforts, such

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as the cumulative taxes between the direct and reverse flows. The presence of representatives of the Public Ministry in the workshop was strategic for bringing confidence and pointing out solutions to these issues. The choice of the types of activities proposed for the workshops is central. The clear definition of the workshop objective drives this choice but we recommend risk analysis as a way of expressing concern and consequently reinforcing transparency. Finally, the workshop was the starting point for preparing the players for the pilot circular system governance meetings.

6 FINAL CONSIDERATIONS

This research lies in the field of applied research. It proposes a framework for closed-loop systems in alignment with the premise that recycling may be a valid strategy to reduce the impact of products not designed with the perspective of Circular Economy from the beginning. One of the practical contributions consists in presenting a five-step method encompassing the planning and implementation of the reverse logistics of EPS/XPS packaging residues on a large scale in Brazil. Many frameworks from the literature are valuable concepts but they do not advance to real applications, possibly due to time constraints, the absence of a leader or pressure that brings the distinct players to work together towards a common objective, the cost constraints of testing the framework, or other reasons.

The creative partnership of an academic research group NIProS and a start-up STup brings a new perspective to the acceleration of applied research projects. Start-ups managers usually recognize the importance of the research in practice. The partnership provided a chance of designing and starting the whole closed-loop system for EPS/XPS recycling in 2 regions of Brazil in a few months with failure in mind, early prototyping and a 'hands-on' perspective. Certainly, the elements discussed in section 5 were also decisive, specially the existence of an empowered and influent client ODc. The academic contributions are described next.

Concerning the method, the premise "designing reverse logistics closed loops for recycling purposes is a way of developing the culture for collaboration in CE" formerly mentioned in the literature, was reinforced in the case. Although it was not detailed in the scope of this text, NIProS could make recommendations to ODc leaders towards innovation. In the long term, they recommended analysing the substitution of plastic with organic alternatives and the reduction of packaging from delivery to attend to Circular Economy principles. The pilot circular project started operations in April 2022. In the middle term, ODc as the main funder, could operate as an incubator and accelerator of the Waste and sorting companies in other regions of the country, as a strategy for scaling up the EPS/XPS recycling capacity in Brazil and increasing revenues. These initiatives comply with the main principles of the Circular Economy in contrast with the starting recycling strategy. This and other collaborative activities arose from this experience among the players. Therefore, we hypothesize that the operation of end-of-pipe projects with different players and partners will pave the way for developing trust and collaboration to innovative endeavours in the circular economy and other fields.

The premise of designing the circular closed loop assuring economy of scales and demand-driven approach was highly favoured by the nature of EPS/XPS. The material attends high recyclability taxes and low losses along the reverse chain. Moreover, it is interesting for large-scale demand industries such as civil construction and polymer manufacturing. We may convert these characteristics into criteria for identification of residues adequate to large scale closed loops. This leads us to the rationale that not every kind of residue will fit large scale closed loops. The interviews and formal content analysis from Step 1 are supportive in this matter. Other advantages of the preliminary interviews include: identification of elements to design the whole supply chain, the direct and reverse flows more consistently; taking the opinion of experts on limitations and operations needed for safely recycling the material; elicitation of requirements and limitations of each player; identification of key players to participate or not in the pilot project and workshop.

We consider the limitations of this paper to deepen the discussion of other relevant findings such as risks, barriers to the success of the project, the role of the population as providers of the post-consumption material, KPIs, business model, communication, and other themes. The factors mentioned in section five are considered generalizable to applications of the method in distinct contexts. The creative partnership between NIProS and STup opens avenues for longitudinal investigations of the case. The continuity of this research previews analysis of the financial viability of the whole system to provide a win-win vision for the players, the analysis of KPIs as references for improvements of the system's performance, and the scaling of the system to other cities and regions in Brazil.

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