



# Logistics performance: critical factors in the implementation of end-of-life management practices in the pharmaceutical care process

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## Abstract

The management of healthcare waste and end-of-life medication coming from different sources are primary challenges faced by public health leaders. Several factors may be considered critical and inhibitive to reverse logistics within the context of waste management processes. If those factors are not addressed, they may become obstacles to reverse logistics implementation. The purpose of this study is to evaluate the effect that critical factors play in the adoption of end-of-life management practices for medication and its influence on logistics performance. Literature provided some critical factors: management factor, collaboration factor, information technology factor, infrastructure factor, politics factor, financial and economic factor, end-of-life management practices, and logistics performance factor. A sample of 67 professionals from the public pharmaceutical care process answered a structured questionnaire. The collected data was analyzed using partial least square-structural equation modeling. The theoretical structural test confirmed eleven out of the fifteen hypotheses considered. The results have indicated that end-of-life management practices exert a direct influence on logistics performance. The analysis confirmed a direct effect of the information technology factor on end-of-life management practices, but not a moderation effect. Findings have contributed to the literature by providing deeper insights into the relationship between end-of-life management practices for medicines and logistics performance. Moreover, it supports health managers' decision-making in the pharmaceutical care process improvement and engagement with solid waste management policies.

**Keywords** Reverse logistics · Pharmaceutical care process · Critical factors · Healthcare waste · End-of-life medication

## Introduction

At a global level, the managers of organizations, governments, and society as a whole have been privy to an array of discussions regarding environmental and ecological issues, involving multiple uncertainties for industries and companies (Kannan et al. 2012). Studies have highlighted these concerns, with a focus on topics ranging from the carbon footprint, reverse logistics aimed at the adoption of environmentally friendly supply chain management (SCM) (Thürer et al. 2019; Kannan et al. 2012), to greening the supply chains (Irani et al. 2017; Gunasekaran et al. 2015; Govindan et al. 2014; Zhu et al. 2007). The adoption of disruptive innovations for the supply chain, such as industry 4.0, is evolving recently to industry 5.0, where priority is given not only to the conservation of the environment and the optimization of resources, but also to people and the development of solutions supported by exponential technologies.

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This new phenomenon gives rise to tools useful for direct logistics with the promise to solve reverse logistics problems (Pourmehdi et al. 2022; Sharma et al. 2022).

Reverse logistics has become a topic of paramount importance within the scope of sustainability, and one of the greatest challenges globally is the management of solid waste (da Silva et al. 2022). Makaleng and Lambert (2021) affirm that managers invest in means of product recovery either due to cost reduction or environmental issues. They long for improvement in their supply chains to meet the United Nations' (UN) goals (Park and Li, 2021).

Reverse logistics may be considered a competitive edge, influencing the economic, social, and environmental performance of organizations (Ali et al. 2018; Govindan et al. 2015), including in the health field. Unconsumed medicine represents a significant source of waste in terms of volume and cost to health systems around the world (Toh and Chew, 2017; Gyanendra et al. 2011) and also forms a major threat to the supply chains of developing nations (Nakyanzi et al. 2010). Factors associated with high costs, time consumption, a lack of experience and training of those involved, scarcity of commercial incentives and collaborations, and ineffective coordination are all considered obstacles to the entire pharmaceutical supply chain (PSC) (Ding, 2018). The uncontrolled disposal of medicines by users has negative impacts on aquatic life (Campos et al. 2017; Daughton and Ternes, 1999; Ekedahl, 2007) and generates high financial costs for governments (Glassmeyer et al. 2009; Langley et al. 2005).

The sense of urgency concerning the pharmaceutical industry lies in the fact that there is a high rate of medicine consumption around the world as clearly shown by Vellinga et al. (2014). Furthermore, market expectations signal that the global pharmaceutical industry will be worth 1.57 trillion dollars by 2023 (Navadhi, 2019). Meanwhile, the pharmaceutical supply chain is considered responsible for significant environmental impacts (Ribeiro et al. 2021; Viegas et al. 2019) and is considered one of the most complex and harmful production systems (Abbas and Farooque, 2020). The pharmaceutical supply chain is part of a wider system named the pharmaceutical care process. Conceptually, the pharmaceutical care process includes the public health systems that select, acquire, store, distribute, and dispense the medicine to each citizen of a country (Brazil, 2001). These direct flows are necessary to assure that citizens have access to medication in the public sector, but medication comes to their expiration date and must be managed. Therefore, this study examines waste management within the healthcare sector and more specifically the end-of-life management practices for medicines inside the pharmaceutical care process.

The impact of the COVID-19 pandemic was especially prevalent in terms of improper handling of healthcare waste

as pointed by Das et al. (2021) and Sarkis et al. (2020). Meanwhile, direct and reverse logistics operations for medication at a pharmaceutical care process level have found themselves completely overwhelmed during the pandemic. End-of-life management practices for medicines include every activity played by professionals inside the pharmaceutical care process viewing the uptake of expired medication returned from the population or internal sectors of the system.

In developing countries, reverse logistics of end-of-life or unused medication in the public sector may reduce overall costs, but understanding the variables that affect reverse logistics of end-of-life medicines in the context of the pharmaceutical care process gains much more relevance in the pandemic context. Although there is a stated conceptual transition from reverse logistics to the wider concept of circular economy (Fischer and Pascucci, 2017; Genovese et al. 2017; Guarnieri et al. 2020), the managers of companies, industry, and the public sector are unable to implement or even manage it efficiently. There is a double challenge since the already complex direct logistics performance of the pharmaceutical care process may be influenced by the implementation of reverse logistics, but to what extent? Different factors can be considered critical to the implementation of reverse logistics and can very often become barriers to the process (Abdulrahman et al. 2014).

Brazilian Law n. 12.305 established the National Policy on Solid Waste (PNRS, Portuguese abbreviation), based on the premise of greater shared responsibility among waste generators, including manufacturers, importers, distributors, traders, citizens, and those overseeing urban solid waste management (Brazilian Policy of Solid Waste, 2010). RDC 222/2018 (Brazil, 2018) is of particular importance, assisting managers of public and private sectors to articulate guidelines for the creation of a management plan for waste generated by the healthcare sector in each Brazilian municipality. However, as pointed out by Pereira et al. (2012), in Brazil, a sectorial agreement is still needed, with clear guidelines for all those involved in the supply chain, including each entity, as it is described in the reverse logistics concept. A lack of disposal standardization was also highlighted by Tong et al. (2011), as many countries still have no established protocols for disposing of medical waste.

In addition, managers at the pharmaceutical care process in Brazil are fully concerned about the performance of the direct logistics giving little attention to the policy on waste and the reverse logistics of end-of-life medicine necessity in such process. Campos et al. (2021a) have demonstrated that reverse logistics in pharmaceutical care process may be of 2 types: (i) reallocation logistics medication that consists of medication that is still within its expiration date. It is part of a redistribution and/or reallocation process from one pharmaceutical unit with a lower

monthly consumption to a unit with higher consumption. The goal of reallocation is to prevent loss of medicine due to expiry and depleted stocks. (ii) Reverse logistics, medication at the end of its useful life, therefore, useless to the citizen or the public health professional use. End-of-use or unused medication reverse logistics would pose the need of quality validation of the product before reuse, to assure that the drug levels are in accordance with treatment needs.

Given the impact on the environment and increased risk for a safe life, this study seeks to fill a gap in the literature, developing and testing a theoretical model to understand critical factors in reverse logistics implementation at the pharmaceutical care process, mainly its impact on logistics performance. The study is supported by the theory of resource-based view (RBV). Based on Abdulrahman et al. (2014) and Campos et al. (2021b), critical factors were categorized in eight dimensions, namely, management factor (MF), collaboration factor (CF), information technology factor (ITF), infrastructure factor (IF), politics factor (PF), financial and economic factor (FEF), end-of-life management practices (EOL-MP), and logistics performance factor (LPF).

The understanding of critical factors in the implementation of reverse logistics for end-of-life medicines is justified by the following reasons:

- The complexity of direct logistics performance in the pharmaceutical care process segment that is responsible for medication provided to the entire population of a country.
- Scarcity of studies on the distribution of medication in the public health sector, even less about the reverse logistics in the same context.
- Information on critical factors may support decision-takers to invest in waste management or enhance managers' engagement to reverse logistics strategies of end-of-life and unused medicines.
- The global crisis linked to the COVID-19 pandemic, especially prevalent within healthcare residue management and chiefly the transition to a sustainable system.
- A lack of quantitative studies geared specifically towards the public pharmaceutical care sector, impacted by high costs and high volumes of medicines wastes.
- The 17 sustainable development goals cited by the UN and that must be fulfilled by the countries (United Nations, 2015). Considering the idiosyncrasies, especially those inherent to each country and each sector, barriers must still be understood and overcome to ensure the successful implementation of reverse logistics.
- There is a conceptual transition from reverse logistics to the wider concept of circular economy, which represents a second life for products; therefore, it is worthwhile to

understand reverse logistics variables behavior since it is part of the circular economy model.

Considering the arguments mentioned before, this study aims to respond to the following research question (RQ): how do critical factors affect the end-of-life management practices for medicines, and how do they influence the logistics performance in the pharmaceutical care process? The objective is to assess the influence of critical factors on end-of-life management practices for medicines and to determine the effect of them on pharmaceutical care process logistics performance.

The LPF used for this study covers three logistics cycles: (i) direct logistics: referring to the distribution of medication to citizens; (ii) reallocation logistics among pharmacies inside the pharmaceutical care process; and (iii) reverse logistics of the medication at the end of its useful life. The contributions of this study evolve from two perspectives. From the theoretical perspective, results contribute to the literature by providing deeper insights into the relationship existing between end-of-life management practices for medicines and logistics performance. From the practical perspective, results may support public health managers' decision-making in the pharmaceutical care process improvement and engagement with solid waste policies.

## Literature review

The generation of health waste increased rapidly during the pandemic episode due to the high consumption of medicines and health items, which has also changed the global dynamics of waste management, waste at a global level (Sharma et al. 2020, Kargar et al. 2020). The new pattern of waste generation in the health area has brought numerous challenges to countries, policymakers, and managers of solid waste, thus requiring a dynamic response from managers to these new challenges (Sharma et al. 2020). The challenge encouraged the countries' governors, such as Brazilians, to formulate strategies to deal with COVID-19 and to demand compliance with the standards used in waste management, like solid health waste.

The implementation of EOL practices, aimed at reverse logistics of residues, involves several stakeholders that run the system. This situation is particularly evident in external practices, such as a specification for suppliers within environmental requirements, auditing of supplier environmental management systems, ecological design, and handling of products returned by clients (Sarkis et al. 2011). According to Govindan and Bouzon (2018), the implementation and management of reverse logistics are dependent on the support and participation of the main parties interested in shared responsibility for the supply chain through the reverse flow

of end-of-life products and in resources that will be necessary for RL operations.

Nevertheless, the literature suggests the importance of considering a theoretical base to explain issues related to product recovery (Kumar and Dixit, 2018). From this perspective, some studies employ different theories, such as the theory of economic transaction costs, institutional theory, and stakeholder theory. A study by Lau and Wang (2009) suggests a combination of these theories to help companies select a system for managing the recovery of end-of-life products. This study applied the resources-based view theory, presented in the next section.

## Resource-based view theory

The theory of a resource-based view allows for an assessment of the structure and behavior of a company (Grant, 1996). The theory suggests that companies can generate above-average rates of return and obtain sustainable competitive results over their competition when well supported by their competencies and essential resources at an organizational level—tangible assets (Barney, 1991). In light of the resource-based view theory, Rehman et al. (2021) highlight that the development of green innovation shifts companies from environmental management to sustainable development, thus achieving a robust environmental effect.

According to the resource-based view outlook, a company is seen as an exclusive package of characteristic resources and capacities, wherein the main task of management is to maximize value through the ideal implementation of existing resources and capacities while developing the company's resource base for the future (Priem and Butler, 2001; Grant, 1996). The theory assumes that the resources and capacities of organizations are valuable and difficult to copy, as they provide the leading sources of sustainable competitive edges (Barney, 2001). Resources are considered assets, capacities, company attributes, organizational processes, expertise, and information that allow a company to conceive and implement strategies to improve competitiveness (Barney, 1999; Sarkis et al. 2011).

According to this view, the managers of a company should be concerned not only with profitability in the present and mid-term growth but also with its future position and the source of its competitive edge. This view calls for explicit strategies about how the company will compete when its current strategy configuration is copied or becomes obsolete (Hart, 1995).

Priem and Butler (2001) suggest that resources should be heterogeneous among companies and that some valuable resources are rare, difficult to imitate, or not replaceable, with companies having specific essential resources. Supported by the theory of contingent resource-based view,

Bag and Gupta (2019) note that the availability of green human capital, that is, the workforce and employees who are engaged in green tasks, is considered a competitive advantage for organizations. Furthermore, companies that recruit and retain human capital achieve higher production and greater sustainable prominence compared to companies that operate without green human capital.

Makhloufi et al. (2022) highlight that via environmental creation, green practices, and cooperation based on innovation, entrepreneurs can benefit and evolve from “environmental management” to “knowledge businesses in sustainable development.” In the study by Kouhizadeh et al. (2021), managerial support and the need for knowledge and experience are considered intangible resources that affect the adoption of blockchain technology for the sustainable supply chain management.

In light of the resource-based view theory, Khan et al. (2022) proposed a model that examined the associations of supply chain connectivity, supply chain information sharing, senior management commitment, and green acceptance of procurement and logistics. The model was developed and validated with 381 employees from manufacturing companies in the United Kingdom. The authors confirmed the positive associations of supply chain acceptance and supply chain information sharing with top management commitment and green procurement and logistics acceptance and also top management commitment with green procurement and logistics and green supply chain management and green procurement acceptance and logistics with green supply chain management (Khan et al. 2022). Likewise, Makhloufi et al. (2022) consider that the development of green innovation causes changes from environmental management to sustainable development, harmonizing relations with the external environment.

## Critical factors in the implementation of reverse logistics in the pharmaceutical care process

Each sector has a specific factor considered critical and that needs to be overcome to ensure the effective implementation of reverse logistics. Examples include studies by Kumar and Dixit (2018) and Erol et al. (2010) involving the electric and electronics sector. They mention that the lack of an information system prevents the attainment of scales of economy, in such a way that it significantly reduces the value captured through the recovery of products, not to mention political and regulatory barriers and a lack of legislation and economic incentive. Similarly, a lack of expertise or infrastructure is also considered critical as mentioned by Massoud et al. (2015).

Within the medicine sector, Yang et al. (2015) mention that a lack of information and expertise concerning environmental impacts, a lack of more conservative medication prescriptions, and no means of safe disposal are also considered hurdles to the management of pharmaceutical residues.

The next section presents a brief description of the eight critical factors based on literature studies.

## End-of-life management practices

Reverse logistics (RL) has become more prominent and widely discussed along with other subsequent topics like circular economy, the growing environmental concerns, 2030 agenda, and social responsibility with the aim of gaining competitive advantages. Industries are moving towards maintaining sustainable production and consumption by considering reverse logistics, maximizing the value creation of end-of-life products, and effectively streamlining business operations (Rajput and Singh 2022). Optimizing drug preparation and dispensing process flows can significantly reduce waste. One source of waste is compounded medication, as leftovers are usually discarded due to the short shelf life after preparation (Smale et al. 2021). Moreover, due to the excessive use of resources, resulting in environmental degradation, it becomes important to integrate reverse logistics and the circular economy (Rajput and Singh 2022), for bringing EOU medication back to the system, for instance.

Supply chain managers face several challenges in reverse logistics management and remanufacturing practices due to uncertainties in product returns and the presence of contradictory organizational goals (Bag et al. 2021). According to Smale et al. (2021), although waste disposal management is widely explored, it would be more effective to prevent the occurrence of drug leftovers in the first place to achieve sustainable supply and use of drugs. Despite the major importance of correct practices for pharmaceutical residue, there is very little awareness regarding the right ways of disposing of medicines (Vellinga et al. 2014). Abbas and Farooquie (2018) posit that it is necessary to prioritize attention to the return flow of medicine to the point of origin, to recover value, and also, to ensure suitable disposal.

According to Viegas et al. (2019), most studies on reverse flow do not cover the diverse EOL-MP routes and present restrictions on how supply chain processes and operations affect reverse flows. A more sustainable pharmaceutical supply chain (PSC) must be implemented to correspond to future operations and management of pharmaceutical products during the entire life cycle (Ding, 2018).

## Management factor

The management factor regards the behavior of senior management in the implementation of RL activities. In many cases, a lack of expertise among managers concerning the benefits generated or a lack of interest among senior management may become a major barrier to the successful implementation of RL (Sirisawat and Kiatcharoenpol, 2018).

Aspects related to technical knowledge and/or expertise among employees and strategic planning are also cited by Massoud et al. (2015), Muduli et al. (2013), and Ravi et al. (2005). The study by Kouhizadeh et al. (2021), more recently, confirmed that lack of management commitment and support has the highest overall prominence of the organizational barrier and is a significant precursor to the other barriers, as the lack of adequate infrastructure. The literature further cites as an important element the number of employees to perform reverse logistics activities, as, oftentimes, employees end up with a higher number of activities in addition to those of day-to-day activities (El Baz et al. 2018; Xia et al. 2015).

Individual behavior is an important element of efficient adherence to the management of solid waste in the health area. Moreira and Günther (2013) studied the primary healthcare center. The authors highlight the challenges of trying to shape people's behavior, teaching them the correct way to segregate waste, and concurrently keeping the team engaged. The team is made of professionals working in health units with different characteristics. And the lack of knowledge of the legislation on the part of health professionals also contributed to the presence of non-conformities. EOL management practices include the monitoring of validity of medication, stock control of expired products, sorting, and collection of products, and these activities depend on individual behavior.

According to Sarkis et al. (2011), the interdependence of supply chain partners, as well as the quality and efficiency of their collaboration, determines the success of the implementation of a green supply chain and, as such, cannot be ignored. The following hypotheses are based on this context:

- Hypothesis 1a. Management factor has a direct effect on end-of-life management practices (EOL-MP).
- Hypothesis 1b. Management factor has a direct effect on logistics performance factor.
- Hypothesis 1c. Management factor has a direct effect on infrastructure factor.

## Collaboration factor

In forward logistics flows, organizations need to create a collaborative environment among the different links or levels of the supply chain, and collaboration becomes

essential to the successful performance of the supply chain (Chen et al. 2007). According to Luthra et al. (2020) and Mahadevan (2019), companies require solid coordination and collaboration among members of the supply chain and to extend these principles to the reverse flow of products. Collaboration in the supply chain is gaining strategic importance in terms of ecological innovation as an integral part of the environmental and innovation strategies of contemporary companies that adopt disruptive technologies (Ocicka et al. 2022).

Network and inter-organizational cooperation is crucial to fostering and facilitating environmental activities (Makhloufi et al. 2022). Luo and Wan (2022) designed an effective recycling system; the strategy of reutilizing physical drugstores and the cooperation between drugmakers and drugstores can significantly enhance the profitability and sustainability of the system. According to Ocicka et al. (2022), companies that cooperate with suppliers and customers (upstream–downstream external collaboration) declared a greater tendency to green their innovations than those that cooperate with only a limited group of partners.

Collaborating with partners helps to improve green practices and strengthen the green organizational culture. Furthermore, increasing environmental awareness refers to the responsibilities of managers to facilitate green entrepreneurship orientation strategies to achieve entrepreneurial eco-opportunities (Makhloufi et al., 2022). For Smale et al. (2021), manufacturers, distributors, prescribers, pharmacists, and patients are jointly responsible for the implementation of waste minimization measures. However, cooperation in the supply chain and waste management is essential. Supply chain entities create inter-organizational links as they have something to gain (Ocicka et al. 2022).

The said collaboration noted within the supply chain is highly critical and may contribute to inter-organizational dynamics, bolstering the capacity to absorb knowledge, share information, structure solutions, and drive the implementation of activities around problems related to environmental issues, cleaner production, and reverse logistics (Van Hoof and Thiell, 2014).

Wagner et al. (2011) point out that collaboration can be looked at as an intangible resource for organizations and may present positive impacts on organizational performance. As such, greater attention is being paid to the creation of ways to encourage supply chain operators to work collaboratively in forward logistics and other operations like reverse flows, to achieve ecological and sustainability goals, as RL processes based on a collaborative network will increase performance and productivity for reverse flow operations (Mahadevan, 2019; Ramanathan et al. 2014). The following hypotheses are based on the presented context:

- Hypothesis 2. The collaboration factor has a direct effect on EOL-MP.

## Information technology factor

Within the scope of technological innovations, the tools arising from industry 4.0, with the use of emerging technologies, have been considered to enhance their use in environmental sustainability actions for the RL and CE areas, as it allows for a better strategic alignment with the goals of organizations (Sun et al. 2022; Kouhizadeh et al. 2019; de Souza Jabbour et al. 2018).

Blockchain systems, combined with the internet of things (IoT) and other digital technologies, are intended to help countries recycle more and reduce impacts on the environment (Parmentola et al., 2022). The combination of different technologies can effectively leverage initiatives that can be used as allies in the hope of creating sustainable value, allowing companies to gain competitive advantage and make the forward and reverse supply chain more sustainable (Ding, 2018).

Garrido-Hidalgo et al. (2019) developed an end-to-end internet of things (IoT)–based solution for reverse supply chain management in industry 4.0. The authors concluded that IoT can be conceived as a tool to facilitate information management in EoL product recovery operations, effectively contributing to the transition to a circular economy. Collaboration may benefit from the information gathered if efficiently shared among stakeholders.

Considering big data technology, Bag et al. (2021) point out as benefits for managers the value of big data analysis to make a better judgment of reverse logistics quality by improving remanufacturing processes to achieve sustainability. It should be noted that the technology itself will not lead to better performance of the reverse logistics system, but the transformation and redesign of services and operations can improve sustainability in the economic, environmental, and social dimensions (Sun et al. 2022).

In the transition to an intelligent paradigm, adopting new and disruptive technologies is not the objective, but the means to enable responsive services and efficient processes. Such technologies can be used to improve the economic, environmental, and social sustainability of reverse logistics systems (Sun et al., 2022). Still very embryonic, it is already possible to find studies introducing the concept of industry 5.0 for solutions in the pharmaceutical industry, as in the study by Sharma et al. (2022). Ghobakhloo et al. (2022, p. 721) revealed that industry 5.0 delivers sustainable development values through 16 functions: circular intelligent products; data sharing and transparency; employee technical assistance; intelligent automation; operational and resource efficiency; open sustainable innovation; renewable

integration; real-time communication; supply chain adaptability; supply chain modularity; system integration and interoperability; service-orientation and personalization; sustainable thinking; upskilling and reskilling; and integrative value network. The 16 function set is based on a roadmap for synergies and complementarities to maximize the value of sustainable development.

However, the implementation of these technologies is often complex and presents challenges and barriers to be overcome by managers. Kouhizadeh et al.'s (2021) findings show that supply chain and technological barriers are the most critical barriers for academics and industry experts. Sharma et al. (2022) highlight the problems with the adoption of high-tech innovations due to the lack of standardization and fair benchmarking policies in industry 5.0.

Within the healthcare environment, technological tools that reinforce automation are extremely important for the performance of daily tasks, reducing errors and costs. IT is a major ally and eliminated the need for manual transcription of drug prescriptions, promoted greater speed in healthcare, and also brought the identification of doses prescribed by doctors through online systems, drug labeling containing all necessary identification, practicality, and safety in optical verification based on barcodes for ordered and dispensed medications (Serafim et al. 2010).

When complying with issues related to RL, companies that invest in improving their competencies and technological abilities consequentially enjoy direct and positive effects on direct and reverse logistics performance (Morgan et al. 2016). Generally speaking, a high level of innovation among organizations allows for the creation of the right conditions to improve their capacity to respond to sustainability-related issues (García-Sánchez et al. 2019; Morgan et al. 2016).

In studies such as those by Chauhan et al. (2016), Mathiyazhagan et al. (2013), and Pérez-Belis et al. (2015), one notes just how the lack of technology can trigger difficulties in the implementation of RL. In a study by Costa and Guarnieri (2018), the main difficulties are linked to limitations in purchase management software as well as inventory. The following hypotheses are based on this context:

- Hypothesis 3a. Information technology factor has a direct effect on EOL-MP.
- Hypothesis 3b. Information technology factor has a moderating effect on the relationship between collaboration and EOL-MP.
- Hypothesis 3c. Information technology factor has a moderating effect on the relationship between management factor and EOL-MP.
- Hypothesis 3d. Information technology factor has a direct effect on the collaboration factor.

- Hypothesis 3e. Information technology factor has a direct effect on the management factor.

## Infrastructure factor

This topic considers people, physical aspects, and storage, with one of the critical points in the execution of RL activities related to infrastructure. Organizational managers must provide a suitable location to temporarily store EOL products that are to be returned to their point of origin. Studies point out that a lack of infrastructure may present a barrier to the RL implementation process (Kumar and Dixit, 2018; Massoud et al. 2015; Meyer et al. 2017; Prakash and Barua, 2015).

The reality faced by many public and private organizations is that they need to find specific third-party companies, according to the characteristics of the product, to correctly recycle and process EOL products (Sivakumar et al., 2018). This also ends up generating transport costs for organizations, and, very often, the hurdle of finding third-party logistics providers (3PLs) ends up discouraging this practice (Prakash and Barua, 2015; Sivakumar et al. 2018).

One of the problems in primary healthcare is the lack of a physical structure with appropriate facilities and equipment for the collection process of managing unwanted drugs (Hosseini-Motlagh et al. 2022). The most significant challenge described in the study by Kandasamy et al. (2022) was the difficulty of reprocessing, followed by the lack of transport and infrastructure. Smale et al. (2021) also mention that if the storage conditions are limited, the drug is more likely to expire before reaching the patient. The following hypotheses are based on the presented context:

- Hypothesis 4. Infrastructure factor has a direct effect on EOL-MP

## Politics factor

Managers are charged with articulating and responding to legal issues and those related to protecting the environment based on the principles of green supply chain management: reduce, reuse, rework, refurbish, reclaim, recycle remanufacture, and reverse logistics, highlighted by Srivastava (2007). From a regulatory perspective, political issues are fundamental, given that based on political guidelines, regulations, and laws of countries, authors like Abdulrahman et al. (2014), Govindan et al. (2016), and Luthra et al. (2011) highlight a lack of government support for economic policies that include EOL products, complicating the RL implementation process.

Smale et al. (2021) affirm that health authorities can enforce waste minimization by creating awareness, providing guidelines on waste minimization measures, or encouraging collaborations and alliances. Public policies were identified as the main drivers and guides for the development of reverse logistics actions by companies. Countries where there are no policies aimed at regulating the production and disposal of medicines have disposal systems with larger polluting potential, in addition to production processes that encourage more waste generation (da Silva et al. 2022). Smale et al. (2021) advocate that, in order to achieve sustainable development goals, policy and governmental changes are necessary, as policymakers should focus on investing in interventions with high potential to reduce the burden and environmental impact of drug waste.

Aquino et al. (2018) reinforce that there are also problems in Brazil with the reverse logistics of medicines that do not have specific legislation, as was the case in Brazil until recently. Since 2020, few have been implemented in Brazilian municipalities, which is provided for in Decree n° 10.388/2020 which institutes the medicine reverse logistics system, preventing the correct disposal of household medicines, with an environmentally appropriate destination. The following hypotheses are based on this context:

- Hypothesis 5a. Politics factor has a direct effect on EOL-MP.
- Hypothesis 5b. Politics factor has a direct effect on management factor.

## Financial and economic factor

Studies have shown that drug waste generates a significant cost to the national health system in many countries (Romanelli and Lucente 2022). The critical factor named financial and economic refers to economic and financial issues that often interfere in reverse logistics implementation. A lack of financial resources is mentioned by Chileshe et al. (2015), Govindan et al. (2014), and Shaharudin et al. (2015) as being an important issue in RL implementation. In general, organizations require financial resources to implement infrastructure, execute activities like training teams to oversee EOL management activities, and provide computerized systems to manage returns.

According to Zhang and Ma (2021), green innovation mediates the relationship between the breadth of environmental management and depth of environmental management and economic performance. Likewise, financial constraints, lack of managerial support, and lack of knowledge and experience influence hesitancy to convert to new sustainable systems (Kouhizadeh et al., 2021). Khan and Ali (2022) mention that the lack of financial

resources and funding, market challenges, and lack of coordination and collaboration across the entire supply chain network were listed as the main barriers while industrial symbiosis, reverse logistics infrastructure, and blockchain technology as the top-ranked enablers. Hosseini-Motlagh et al. (2022) present a contract model based on the sharing of cost savings associated with drug disposal that can maximize supply chain profitability and coordinate the two levels of the reverse chain under competition. The results reveal that companies enjoy considerable monetary benefit, better social image, and higher level of sustainability using the proposed scheme. In addition, government penalties imposed on companies are also noticeably reduced.

Abdulrahman et al. (2014) point out that a lack of funds for return monitoring systems is a critical barrier to the RL implementation process. Given the setup of public institutions, a collaborative relationship with green suppliers is often limited by restricted budgets (Costa and Guarnieri, 2018). The following hypotheses are based on this context:

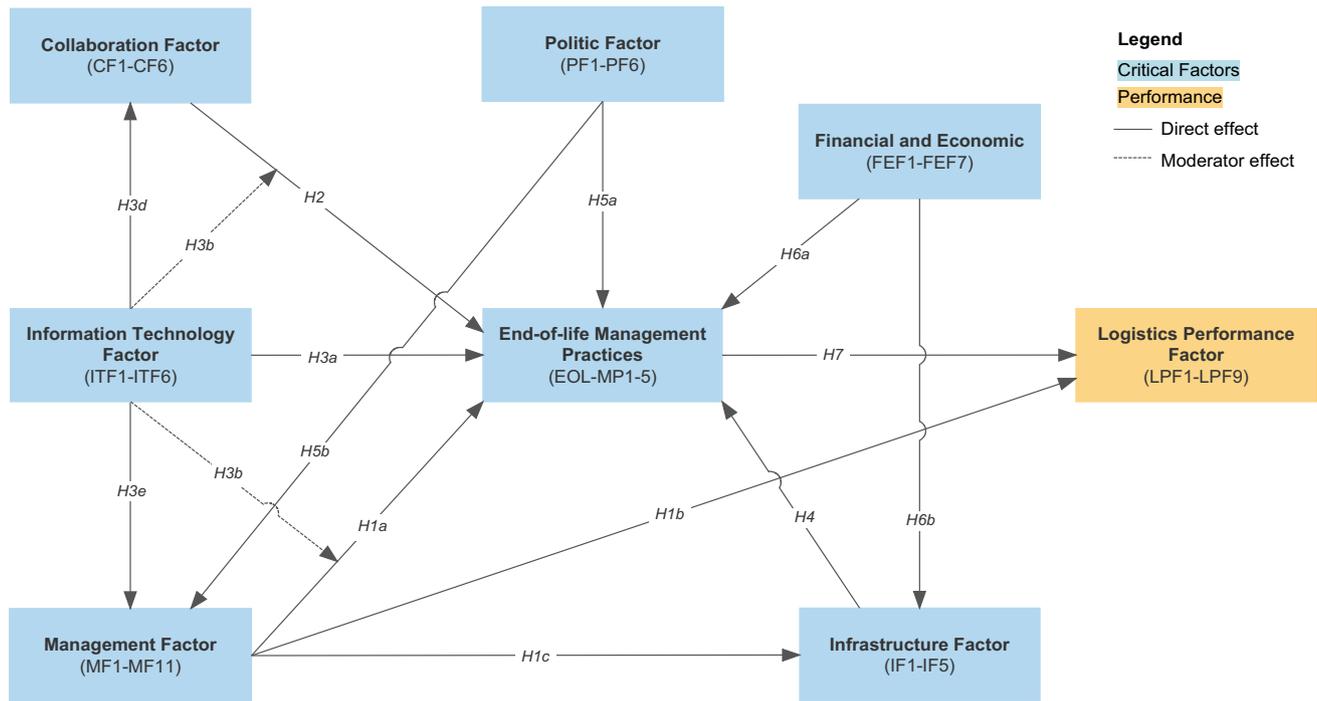
- Hypothesis 6a. Financial and economic factor has a direct effect on the EOL-MP.
- Hypothesis 6b. Financial and economic factor has a direct effect on the infrastructure factor.

## Logistics performance factor

The LPF construct considered variables relative to medicine delivery time to patient; control of checking and receiving in the material management system for medication and input orders; time required for reallocating surplus medication and inputs; reduction in medication and input loss due to expiration; control of medicine and input expiration dates in stock; control of medication and inputs not in stock; control of medication and inputs close to their expiration dates; delivery times for medication and inputs orders through the medication dispensary; and suitable storage of medication and inputs. Therefore, this factor is measured by the performance of direct and reverse variables, and it is dependent on qualified personnel and processes.

Smale et al. (2021) affirm that pharmacists can contribute with EOL-MP through proper inventory management, improving drug preparation processes, optimizing dispensing processes, and redistributing unused drugs. The findings highlight that blockchain can affect supply chain performance directly—through one of its key technological capabilities—and indirectly through the broader business project through which blockchain technology is implemented (Markus and Buijs, 2022).

The capacity to offer efficient healthcare services with acceptable performance, catering to the needs of society,



**Fig. 1** Model proposed for this research, with direct and moderate effects

depends on managerial capacity and the coordination of logistics activities within a healthcare system, systemically and effectively (La Forgia and Couttolenc, 2008; Longaray et al. 2018). Smale et al. (2021) show that the role of distributors involves storing and distributing drug inventories to pharmacies. During these processes, drug waste can derive as a consequence of drug expiration.

Despite patient care being the primary concern within healthcare sectors, activities related to logistics are critical to ensuring supply security, availability, and accessibility. The interaction among the clinical, material, and information flows is now essential to improve operational performance for logistics processes and to obtain an integrated supply chain (Moons et al. 2019).

The correct and rational distribution must guarantee that the delivery process is efficient, based on a pre-established flow chart, preventing delays and ensuring products will reach users in the correct volumes and with the desired quality (Moons et al. 2019).

An efficient information and control system means that distribution is monitored constantly, providing updated information at any time regarding the “physical and financial” position of inventory, the volumes received and distributed, consumption and demand data for each product, maximum and minimum stock, replacement points, volumes acquired, and other information necessary to optimal management (Serafim et al. 2010).

The following hypotheses is based on this context:

- Hypothesis 7. EOL-MP has a direct effect on the logistics performance factor.

## Methods

This research was performed in five stages: (i) literature review presented in the former section; (ii) model design; (iii) questionnaire development and data collection; (iv) data analysis, and (v) interpretation and recording of results. Aimed at understanding the critical factors in waste management and geared towards reverse logistics implementation for medication in the pharmaceutical care process (PCP), the construct variables and hypotheses created for the study were developed based on previously consulted literature. Figure 1 presents the constructs together with the study hypotheses of the proposed model.

The structure of the proposed model presented in Fig. 1 was developed, based on the extensive review and classification of critical factors in the implementation of reverse logistics, previously presented by Campos et al. (2021a, b). Based on this structure, a new round of interviews was convened with the five main managers from COORAF involved in the process and three external experts with vast knowledge of waste management. We presented the concept of each factor and what elements the previous literature brought as indicators within each factor. The final instrument underwent several adjustments until it was possible to come at a clear and

easy-to-understand version for all professionals, including the logistical process of end-of-life medications.

After adjusting the items according to the suggestions, an online questionnaire was created available using the Google Forms® platform. We followed the guidelines of online surveys that apply based on the methodology described by Menegaki et al. (2016). Each respondent had the option of selecting the level of agreement with several number of statements presented, based on a 7-point Likert scale (ranging from “1 = totally disagree” to “7 = totally agree”).

The questionnaire, containing 55 items (Table 1, see Appendix), was available for approximately 4 months, to allow pharmaceutical professionals to respond. Ten local district pharmacies were part of the sample of interviewees. These units belong to the pharmaceutical care system in the city of Porto Alegre, Brazil, and managed by the high-level pharmacists from COORAF. However, due to political issues that involved outsourcing health unit work teams, the number of respondents was restricted only to ten local district pharmacies in the city. We have decided to exclude the new work team as respondents because they did not possess sufficient and expertise in the activities to complete the form, which would jeopardize the results obtained.

We informed the professionals that they would be asked to respond to the research instrument sent via e-mail by the coordinator. Moreover, they would receive the research approval documentation from the ethics committee, the confidentiality terms in the treatment, and dissemination of collected data. The pharmacist responsible for the Pharmaceutical Assistance Division (COORAF) responded to the research pre-test instrument and pointed out some more pertinent changes that were incorporated into the final version.

The questionnaire was adjusted once again and sent to other municipalities in the region, with both centralized and non-centralized dispensary characteristics. This included 68 additional respondents, totaling 78 in all. From this group, 67 questionnaires were fully completed, and the remaining were removed.

The 67 respondents were distributed in the city of Porto Alegre in Brazil and also in the smaller neighboring municipalities. As for the characteristics of the respondents, 86.6%, that is, 58 of them, occupy the role of pharmacists or technical pharmacist or coordination, and 13.4%, that is, 9 of them, occupy managerial functions of coordination and pharmaceutical assistance directorate or even auxiliary and responsible administrative agent technician. Table 2 presents the profile of the respondents.

The number of respondents is not considered a limiting factor to the study. The sample should be 74 units in analysis with G\*Power software (Faul et al. 2007). The difference from 74 to 67 impacts the type 2 error ( $\beta$ ), with an increase from 5 to 6.8%, which is considered acceptable. The reason to accept lies in the fact that other variables also affect

the phenomenon and they cannot be controlled. Moreover, a similar number of respondents was previously identified in the study by Chileshe et al. (2018) with 48 respondents.

## Results

For the analysis, structural equation modeling (SEM) was employed using partial least squares (PLS) and the software WarpPLS 6.0 (Kock, 2017). The PLS statistic is justified as it is a model built on the theoretical framework consulted and the items from each construct were considered reflexive and with a restricted sample.

The model was initially estimated to include 55 items. Following an analysis of factor loads for the items, four were excluded for presenting a factor loading below 0.5, as recommended by Hair et al. (2009). The items removed were the following: in the ITF construct, the “ITF1—Deliver medication to patients via DIS” item was excluded. In the PF construct, the “PF4—Flaws in law/regulations regarding solid healthcare waste in the public sector” item was excluded. In the EOL-MP construct, the “EOL-MP4—Deliver expired medication to NDM-CAF employees” item was excluded. In the LPF construct, the “LPF1—Delivery time for medication and inputs to patients” item was excluded.

Table 3 presents the results for convergent validity, following the removal of the aforementioned items. All items maintained present factor loading higher than the recommended 0.5. To assess internal consistency, average variance extracted (AVE) and composite reliability (CR) were used as parameters. To be representative, this index must be higher than 0.7 and the values for Cronbach’s alpha to estimate measurement error and true composite weights. Thus, all the indexes were satisfactory as presented in Table 3.

Considering the items with higher factor loading highlighted in bold in Table 3, the findings show that the management factor construct include “MF7—Support from COORAF (managers) in reallocating surplus medication and inputs among units,” “MF8—Support from partner pharmaceutical companies for RL involving medication and inputs,” and “MF10—Support from NDM-CAF for RL involving medication and inputs.” The COORAF managers perform the mediation and coordination of the entire pharmaceutical care system. The NDM-CAF is the warehouse where returned medicine stocks are stored and the new medicine from suppliers, as well. Respondents placed relevance on the relationship or partnership expected to be established with suppliers for reverse logistics of expired medication. The medicines like other chemicals must be adequately discarded, and suppliers have the expertise in this; moreover, NDM-CAF has limited space for storage of expired products. This is reinforced in the collaboration factor results, as follows.

**Table 1** Constructs and variables

Construct	ID	Description
Management factor (MF)	MF1	Workers in sufficient numbers to perform RL activities for medication and inputs
	MF2	Workers with technical knowledge/expertise involving RL for medication and inputs
	MF3	Workers with the capacities and/or trained with regard to separating expired medication and inputs
	MF4	Workers committed to/motivated by issues related to pharmaceuticals and input waste management
	MF5	Capacity building and/or training for workers on separation practices for expired medication and inputs
	MF6	Coordination support for RL involving medication and inputs
	MF7	Coordination support to reallocate surplus medication and inputs among basic health units
	MF8	Support partner pharmaceutical companies for RL involving medication and inputs
	MF9	Support partner pharmaceutical companies in reallocating surplus medication and inputs among units
	MF10	Support from NDM-CAF for RL involving medication and inputs
	MF11	Support from NDM-CAF to reallocate surplus medication and inputs among basic health units
Collaboration factor (CF)	CF1	Sharing of information
	CF2	Reliability in sharing information
	CF3	Collaboration among workers involving RL activities for medication and inputs
	CF4	Coordination collaboration for RL activities involving medication and inputs
	CF5	Collaboration of partner pharmaceutical companies in reallocating surplus pharmaceuticals
	CF6	Collaboration of partner pharmaceutical companies for returning expired medication or sanitary collection
Information technology factor (ITF)	ITF1	Deliver medication to patients using the DIS system
	ITF2	Reallocate surplus medication to partner pharmaceutical companies using the GMAT system
	ITF3	Monitor medication expiry dates via the GMAT system
	ITF4	Generate information on expired medication and input volumes via the GMAT system
	ITF5	Return expired medication to the NDM-CAF in (SOP 10) via the GMAT system
	ITF6	Return medication for sanitary waste collection NDM-CAF in (SOP 10) via the GMAT system
Infrastructure factor (IF)	IF1	Receive reallocated medication in a usable condition
	IF2	Store expired medication or inputs delivered by the population
	IF3	Temporarily store expired medication or that no longer suited to use, which shall be returned to NDM-CAF
	IF4	Transport medication in conditions suitable for use from one unit to another, planned by partner pharmaceutical companies
	IF5	Store medication in conditions suited to use which has been returned by patients that left my stock
Politic factor (PF)	PF1	I know pertinent healthcare solid waste legislation
	PF2	I fulfill the task of raising awareness among the population regarding the rational use of medication and inputs
	PF3	I fulfill the task of raising awareness among the population regarding the disposal of medication and inputs
	PF4	There are flaws in the law/regulations regarding healthcare solid waste in the public sector
	PF5	Auditing occurs with regard to correctly managing healthcare solid waste generated by the city
	PF6	There are public policies for the implementation of reverse logistics for medication in the public healthcare sector

**Table 1** (continued)

Construct	ID	Description
Financial and economic factor (FEF)	FEF1	Make improvements to the GMAT system
	FEF2	Hire outsourced services to ensure correct collection and disposal of all waste generated
	FEF3	Tender the purchase of materials for permanent education actions (trash cans, adhesives with symbols, plastic bags, etc.)
	FEF4	Store and handle waste until it is sent to the NDM-CAF
	FEF5	Improve medication and input storage areas
	FEF6	Improve medication and input separation areas
	FEF7	Improve medication and input delivery areas
EOL management practices (EOL-MP)	EOL-MP1	Monitoring the validity of medication and inputs in stock via the GMAT system
	EOL-MP2	Notification of expired medication sent to partner pharmaceutical companies and the NDM-CAF
	EOL-MP3	Request the collection of expired medication and inputs from partner pharmaceutical companies/NDM-CAF
	EOL-MP4	Delivery of expired medication to NDM-CAF employees
	EOL-MP5	Separation of medication and inputs returned by the population
Logistics performance factor (LPF)	LPF1	Delivery time for medication and inputs to patients
	LPF2	Check and receipt control in the GMAT system for medication and input orders
	LPF3	Time required for reallocation of surplus medication and inputs
	LPF4	Reduction in medication and input loss due to expiration
	LPF5	Expiry control of medication and inputs in stock
	LPF6	Control of medication and inputs not in stock
	LPF7	Control of medication and inputs close to expiry
	LPF8	Order delivery time for medication and inputs by NDM-CAF
	LPF9	Suitable storage of medication and inputs

Caption: GMAT, material management system; DIS, medicine dispensing system; NDM-CAF, medicine distribution center of the Pharmaceutical Assistance Coordination

**Table 2** Profile of respondents

Variable	Value	Frequency (f)	Percentage
Gender	Male	10	14.9%
	Female	57	85.1%
Experience	From 3 to 6 months	4	6.0%
	From 6 months to 1 year	5	7.5%
	From 1 to 4 years	16	23.9%
	From 5 to 9 years	25	37.3%
	From 10 to 14 years	8	11.8%
	From 15 to 20 years	5	7.5%
	Over 20 years	4	6.0%
Age	21–30	15	22.4%
	31–40	36	53.7%
	41–50	14	20.9%
	> 50	2	3.0%
Education	Undergraduate	61	91.0%
	Specialist/MBA	3	4.5%
	Master’s degree	3	4.5%

In the collaboration factor construct, items with higher factor loading were “CF5—Collaboration of partner pharmaceutical companies in reallocating surplus medication,” “CF6—Collaboration of pharmaceutical companies in returning expired medication or for sanitary collection,” and “CF1—Sharing of information.” Information exchange is at the same time demanded in collaboration contexts as the means for development of trust and cooperation.

In the information technology factor construct, items with a higher factor loading included “ITF5—Return expired medication to the NDM-CAF in (SOP 10) via GMAT,” “ITF6—Return medication for sanitary collection in (SOP 10) via GMAT,” and “ITF3—Monitor medication expiry dates via the GMAT.” The functions of GMAT were key to controlling the end of life of medication in the pharmaceutical care system studied. The respondents recognized the utility of the software functions in spite of the managers have been training more people to use the software properly at the time of interviews.

For the infrastructure factor construct, items with a higher factor loading included “IF2—Store expired medication or

**Table 3** Convergent validity and internal consistency reliability results

Constructs	Item	Cross loading	SE	AVE	CR	Cronbach's alpha
Management factor (MF)	MF1	0.770	0.095	0.740	0.969	0.964
	MF2	0.839	0.092			
	MF3	0.814	0.093			
	MF4	0.811	0.093			
	MF5	0.727	0.096			
	MF6	0.892	0.091			
	MF7	0.938	0.089			
	MF8	0.932	0.090			
	MF9	0.899	0.091			
	MF10	0.929	0.090			
	MF11	0.883	0.091			
Collaboration factor (CF)	CF1	0.782	0.094	0.573	0.889	0.849
	CF2	0.717	0.096			
	CF3	0.697	0.097			
	CF4	0.704	0.097			
	CF5	0.832	0.093			
	CF6	0.798	0.094			
Information technology factor (ITF)	ITF2	0.638	0.099	0.539	0.853	0.783
	ITF3	0.735	0.096			
	ITF4	0.683	0.097			
	ITF5	0.834	0.093			
	ITF6	0.766	0.095			
Infrastructure factor (IF)	IF1	0.824	0.093	0.669	0.910	0.875
	IF2	0.871	0.091			
	IF3	0.809	0.093			
	IF4	0.856	0.092			
	IF5	0.722	0.096			
Politics factor (PF)	PF1	0.778	0.094	0.582	0.874	0.820
	PF2	0.794	0.094			
	PF3	0.763	0.095			
	PF5	0.686	0.097			
	PF6	0.789	0.094			
Financial and economic factor (FEF)	FEF1	0.849	0.092	0.741	0.952	0.941
	FEF2	0.773	0.095			
	FEF3	0.886	0.091			
	FEF4	0.752	0.095			
	FEF5	0.919	0.090			
	FEF6	0.923	0.090			
	FEF7	0.906	0.090			
EOU/EOL management practices	EOL-MP1	0.742	0.095	0.643	0.876	0.809
	EOL-MP2	0.877	0.091			
	EOL-MP3	0.898	0.091			
	EOL-MP5	0.666	0.098			
Logistics Performance Factor (LPF)	LPF2	0.743	0.095	0.612	0.925	0.905
	LPF3	0.792	0.094			
	LPF4	0.806	0.093			
	LPF5	0.910	0.090			
	LPF6	0.851	0.092			
	LPF7	0.891	0.091			
	LPF8	0.526	0.103			
	LPF9	0.667	0.098			

**Table 4** Results of discriminatory validity

	MF	CF	ITF	IF	PF	FEF	EOL-MP	LPF
MF	<b>(0.860)</b>							
CF	0.652	<b>(0.757)</b>						
ITF	0.457	0.426	<b>(0.734)</b>					
IF	0.528	0.434	0.314	<b>(0.818)</b>				
PF	0.667	0.486	0.458	0.529	<b>(0.763)</b>			
FEF	0.482	0.443	0.428	0.611	0.415	<b>(0.861)</b>		
EOL-MP	0.618	0.565	0.513	0.511	0.652	0.565	<b>(0.802)</b>	
LPF	0.509	0.536	0.606	0.363	0.510	0.494	0.650	<b>(0.782)</b>

inputs delivered by the population,” “IF4—Transport medication in conditions suitable for use from one unit to another, planned by partner pharmaceutical companies,” and “IF1—Receive reallocated medication in a usable condition.” The NDM-CAF limited storage space is closely related with items considered relevant in this factor.

For the politics factor construct, items with a higher factor loading included “PF2—I fulfill the task of raising awareness among the population regarding rational use of medication and inputs,” “PF6—There are public policies for the implementation of reverse logistics for medication in the public healthcare sector,” and “PF1—I know pertinent healthcare solid waste legislation.” Prior study of this group (Campos et al. 2017) reveals that pharmacists are in a good position either to collect unused medications and to educate patients to this task, and part of the respondents in this investigation are pharmacists. Nevertheless, they depend on the existence of public policies to support them.

For the financial and economic factor construct, items with a higher factor loading included “FEF6—Improve medication and input separation areas,” “FEF5—Improve medication and input storage areas,” and “FEF7—Improve medication and input delivery areas.” The respondents’ attention was focused on investments to improve infrastructure for storage of the medication, more than on investments for hiring outsourced services, software improvements, or buying utilities. This may be explained by the limitations of lower level managers in public departments on deciding for infrastructure changes.

For the EOU/EOL management practices construct, items with a higher factor loading included “EOL-MP3—Request the collection of expired medication and inputs from partner pharmaceutical companies/NDM-CAF,” “EOL-MP2—Notification of expired medication sent to partner pharmaceutical companies and the NDM-CAF,” and “EOL-MP1—Monitoring the validity of medication and inputs in stock via the GMAT system.”

In the logistics performance factor construct, items with a higher factor loading included “LPF5—Expiry control of medication and inputs in stock,” “LPF7—Control of medication and inputs close to expiry,” and “LPF6—Control of medication and inputs not in stock.” Curiously, items

concerning the length of time of time for delivery or displacements in the chain were not considered relevant for logistics performance in the perception of respondents.

Table 4 presents the correlation results for discriminant validity. In the diagonal (**in bold**), the values show that the square root of the average variances extracted (AVEs) are higher than the other correlation values, in conformity with that recommended in the literature.

Further considerations included adjustment indexes for the average path coefficient (APC) = 0.357,  $p < 0.01$ ; average R-squared (ARS) = 0.472,  $p < 0.001$ ; average adjusted R-squared (AARS) = 0.456,  $p < 0.001$ ; average block VIF (AVFI) = 1.362, ideally acceptable if  $\leq 3.3$ ; and average full collinearity VIF (AFCVIF) = 2.184, ideally acceptable if  $\leq 3.3$ . The model also proved suitable in the indexes, Tenenhaus GoF = GoF (GOF) = 0.549, considering that 0.10 is small,  $\geq 0.25$  is medium, and  $\geq 0.36$  is large; Sympton’s paradox ratio (SPR) = 1.000, acceptable if  $\geq 0.7$  and ideally equal to 1; R-squared contribution ratio (RSCR) = 1.000, acceptable if  $\geq 0.9$  and ideally equal to 1; statistical suppression ratio (SSR) = 1, acceptable if  $\geq 0.7$ ; and nonlinear bivariate causality direction ratio (NLBCDR) = 1.000, acceptable if  $\geq 0.7$ .

Figure 2 presents a model of the final path diagram, followed by a summary of the relationships among the constructs that were confirmed and refuted.

Table 5 presents the hypotheses that were tested with the direct effect and also the moderator effect. The value of  $p < 0.05$  was used as a baseline to determine the significance of direct and moderating relationships. In total, 15 hypotheses were tested, with thirteen having a direct effect and two with a moderating effect, totaling eleven confirmed hypotheses and four that were rejected.

As shown in Fig. 2 and Table 5, the management factor had a slightly negative effect on end-of-life management factor ( $\beta = -0.04$ ,  $p = 0.36$ ) which means H1a was rejected. The perception of respondents may be influenced by their operational position in the pharmaceutical care system. They valued other aspects more than the management as the financial and IT. Management factor had a positive effect on the logistics performance factor ( $\beta = 0.259$ ,  $p = 0.001$ ) confirming H1b. Management factor had a positive effect on infrastructure

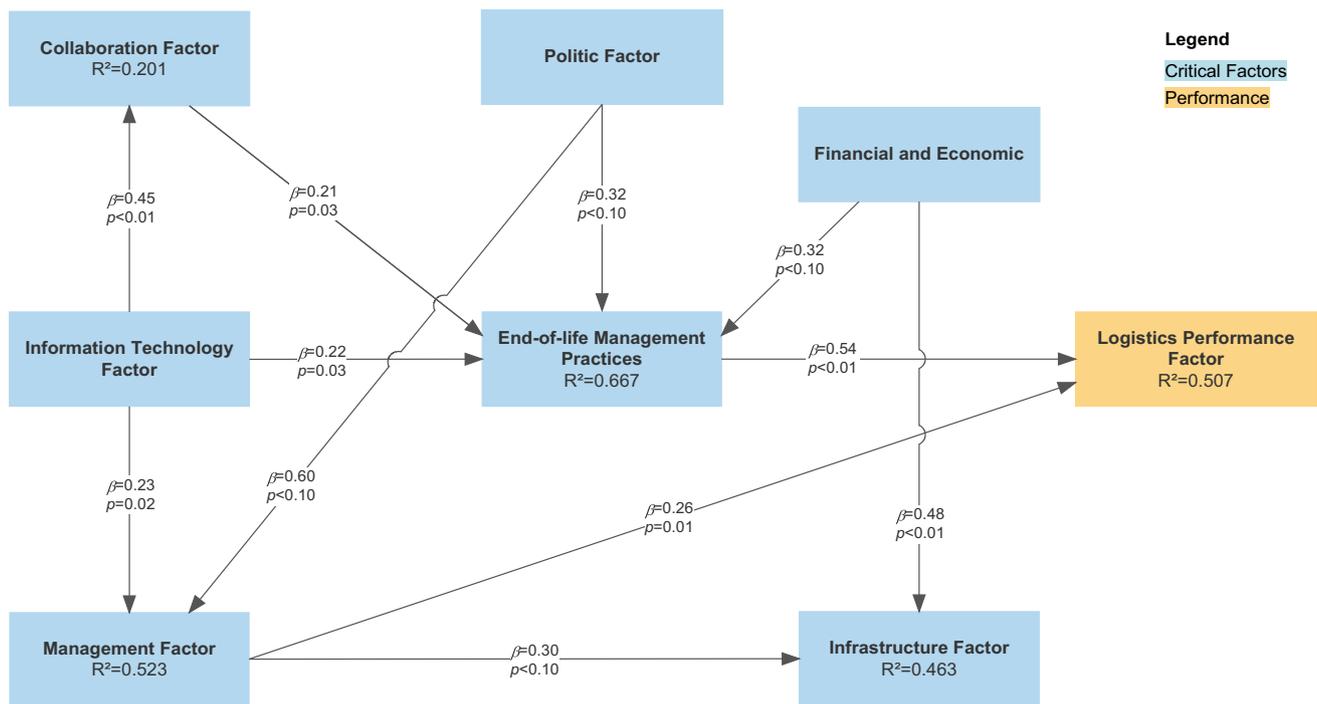


Fig. 2 Result of the path diagram with confirmed hypotheses

Table 5 Results of the hypotheses tests

Hypotheses	Coefficient ( $\beta$ )	p value	Decision
H1a—MF → EOL-MP	-0.04	0.36	Rejected
H1b—MF → LPF	0.26	0.01	Accepted
H1c—MF → IF	0.30	<0.01	Accepted
H2—CF → EOL-MP	0.21	0.03	Accepted
H3a—ITF → EOL-MP	0.22	0.03	Accepted
H3b—ITF → CF → EOL-MP	0.10	0.21	Rejected
H3c—ITF → MF → EOL-MP	0.09	0.23	Rejected
H3d—ITF → CF	0.45	<0.01	Accepted
H3e—ITF → MF	0.23	0.02	Accepted
H4—IF → EOL-MP	0.03	0.40	Rejected
H5a—PF → EOL-MP	0.32	<0.01	Accepted
H5b—PF → MF	0.60	<0.01	Accepted
H6a- FEF → EOL-MP	0.32	<0.01	Accepted
H6b—FEF → IF	0.48	<0.01	Accepted
H7—EOL-MP → LPF	0.54	<0.01	Accepted

( $\beta=0.302, p=0.001$ ), confirming H1c. Although the respondents do not recognize the importance of management decisions on end-of-life management practices, they perceive the importance of management (possibly higher level managers) on deciding for infrastructure changes, as mentioned before. The collaboration factor had a positive effect on end-of-life management practices factor ( $\beta=0.210, p=0.003$ ) confirming H2. Information technology factor had a positive effect on

end-of-life management practices factor ( $\beta=0.220, p=0.03$ , confirming H3a. There was no moderating effect between ITF→CF→EOL-MP and ITF→MF→EOL-MP ( $\beta=0.10$  and  $\beta=0.09$ , respectively, and presented  $p=0.21$  and  $p=0.23$ , also respectively), which means that H3b and H3c were rejected. Information technology factor had a positive effect on collaboration factor ( $\beta=0.448, p\leq 0.01$ ), confirming H3d. Information technology factor had a positive effect on management factor ( $\beta=0.228, p=0.02$ ) confirming H3e. Infrastructure factor was not related to end-of-life management practices factor ( $\beta=0.03, p=0.40$ ), meaning H4 was rejected. In this study, the end-of-life management practices have concentrated tasks that are performed via software more than via physical infrastructure. Politics factor had a low positive effect on end-of-life management practices factor ( $\beta=0.318, p\leq 0.01$ ), confirming H5a. Politics factor had a positive effect on management factor ( $\beta=0.596, p\leq 0.01$ ) confirming H5b. Policies may influence decisions more on the high management level than on the operational management level, but the management levels are interdependent, which may explain these findings. Financial and economic factors had a positive effect on end-of-life management practices factor ( $\beta=0.325, p\leq 0.01$ ) confirming H6a. Financial and economic factor had a positive effect on infrastructure factor ( $\beta=0.485, p\leq 0.01$ ) confirming H6b. Finally, end-of-life management practices factor had a positive effect on the logistics performance factor ( $\beta=0.596, p\leq 0.01$ ) confirming H7. This is clear since the

**Table 6** Inner model analysis results

Latent variables	R <sup>2</sup>	AdjR <sup>2</sup>	Q <sup>2</sup> predictive validity	Full col-linearity VIF
MF	0.523	0.508	0.523	2.578
CF	0.201	0.188	0.201	1.988
ITF	–	–	–	1.719
IF	0.463	0.447	0.476	1.953
PF	–	–	–	2.334
FEF	–	–	–	1.997
EOL-MP	0.667	0.646	0.667	2.655
LPF	0.507	0.491	0.513	2.245

MF, management factor; CF, collaboration factor; ITF, information technology factor; IF, infrastructure factor; PF, policy factor; FEF, financial and economic factor; EOL-MP, end-of-life management practices; LPF, logistics performance factor

logistics performance is actually dependent on the operations described under the EOL-MP factor.

Concerning the empirical test of the proposed structure, statistical indicators presented a suitable quality level, as presented in Table 6.

## Discussion

The management of waste from healthcare services is a complex and current issue. In this study, the COORAF manager's mediation of the entire system has been important to achieve the pharmaceutical care goal which is "to deliver the correct medicine to the patient, in time and support him/her with valuable healthcare information." Taking into consideration the resource-based theory, the current mid-level manager team at COORAF represents a valuable resource difficult to imitate or substitute. The management team has a broad and systemic perspective of the process and has supported the different chain members by providing information, technology, and resources for both the development of the direct and the reverse flow of medicines in the system. Nevertheless, as described by Fischer and Pascucci (2017), managers are still advancing in managing it efficiently. Reverse flows nowadays in the system studied are restricted to internal flows of medication still in condition of being consumed.

Results show that data adapted well to the structure of the theoretical model presented and, in general, it represents the pharmaceutical care process focus of this investigation. The resource-based theory (Priem and Butler, 2001) suggests that resources that are valuable, rare, difficult to imitate, and nonsubstitutable best position a firm for long-term success. Capabilities are needed to bundle, manage, and otherwise exploit resources in a manner that provides value-added to customers and creates advantages over competitors. Despite

El Baz et al. (2018) and Xia et al. (2015) pointing the number of employees as an important element to perform reverse logistics activities, in this public environment, to hire people is a limiting factor. The COORAF high management is always striving to perform better with the same number of professionals and pharmacists.

Therefore, the respondents in this study operate the direct and reverse flow of medicines in the system. They are under the supervision of the management team from COORAF, and results show at least two aspects that contribute to the logistics performance. On one side, collaboration, information technology, policies, and financial factors revealed to have an influence on the end-of-life practices that impact the logistics performance of medication. Luo and Wan (2022) had already described collaboration among private physical drugmakers and drugstore as enhancers of the profitability and sustainability of the system. On the other side, the management is influenced by policies to place an impact on the logistics performance, either.

Logistics performance is very important to the objective of the pharmaceutical care process. Therefore, the findings point to the types of resources that should be developed in this system, like training the people to collaborate for direct and reverse logistics, use of information technology tools, and development of new. It is important to mention that the COORAF managers make a very good job concerning these aspects, with the exception of information technology tools that must be developed by internal department of the city hall with limited budgets.

However, other studies have also been looked at, with a focus on subsidizing sustainable management tools for companies and also for the industrial sectors (Fischer and Pascucci, 2017; Viegas et al. 2019) aimed at adding value to materials and products, maximizing the life cycle, regeneration of the end-of-life, and, thereby, introducing precepts of value recovery (Kouhizadeh, et al. 2019). Results showed that based on support from senior management and the support of partner pharmaceutical companies in the three cycles of logistics (forward, reallocation, and reverse), it is possible to have a major impact on logistics performance, which converges with the literature.

Although not expected, the rejection of H1 may be justified by the fact that the sites investigated in this study experience lower volumes of expired medication. The volumes are generally the consequence of returns flows of EOL medication within the current pharmaceutical care network/system. There is still no decree regulating EOL medication coming from patients, and therefore, such return flows are not frequent.

Literature, on the contrary, defends the relevance of senior managers for RL (Sirisawat and Kiatcharoenpol, 2018). In practice, under the conditions of the studied network, the COORAF managers are three well-qualified pharmaceutical

professionals that handle end-of-life reverse logistics out of 145 healthcare establishments (FD, UBS). They represent the actions from the management factor. As these three professionals are part of the system coordination, and there is strong integration among coordination management professionals, the end-of-life reverse logistics within the network operates quite well. However, if all the complexity of collecting and disposing of end-of-life medication coming from the population can be implemented, it would be exceedingly difficult to cope with this challenge, considering the current structure (Campos et al. 2021b). The core business of the pharmaceutical care network is to deliver value via forward logistics, which is well structured for that. Therefore, according to the resource-based theory, strategic resources for RL should be defined to provide the foundation to develop firm capabilities that can lead to superior performance in the middle run and over time.

In case the Federal Decree n. 10.388 (5th June, 2020) takes effect, it institutes end-of-life/end-of-use reverse logistics for medication coming from the population. Therefore, the management factor must be reviewed and adapted to satisfy the resulting complexity.

It is expected that simply expanding the service already provided by partner pharmaceutical companies will not consider the peculiarities of the reverse logistics problem for medication coming from the population. The NDM-CAF (acronym for the local pharmaceutical warehouse), for example, as a necessary structure, is already at its resource limit in catering to the three logistics cycles (forward, reallocation, and reverse). It would certainly fail to cope with medication coming from the population. As such, recommendations may include the creation of a new strategic unit within the network to deal solely with end-of-life/end-of use reverse logistics. Moreover, they may outsource some reverse logistics activities. The requirements for reverse logistics should be developed in cooperation with the pharmaceutical care coordination, the NDM-CAF managers, and the municipal health department managers.

The rejection of H3b and H3c is justified by the fact that collaboration and sharing of the information provided by COORAF managers and also the support of partner pharmaceutical companies, for activities related to stock control, reallocation of surplus, and expired medication, are sufficient. In this case, information technology did not moderate, with no effect on the intensity of how this happens. Trust is seen as an important element for collaboration and effective communication among parties in the case studied and in literature. They are inseparable from collaboration as highlighted by Paula et al. (2019).

On the other hand, the information technology factor (ITF) construct variables with the highest factor loading are those dealing with information system functions related to RL for EOL medication. This construct had a positive

and direct effect on MF, CF, and EOL-MP constructs. This greater emphasis was expected, as the management system is a tool to support collaborative work in the pharmaceutical care network, geared towards EOL medication. The ITF moderation effect (an operational character) on the MF (strategic character) on EOL-MP (operational character) was not observed. The ITF construct was prepared with an emphasis on the currently existing IT system functionalities of the studied pharmaceutical care network, which presents high operational characteristics.

In case the IT system functionalities focused on aspects like capacity building, the collection and analysis of data for decision-making, and RL performance analysis, perhaps the moderation effect could have been observed. In addition, IT features as a major resource for organizations and particularly for PCP. In this study, it has affected directly EOL-MP, MF, and CF constructs. The underlying literature shows that IT resources are necessary for effective decision-making on RL (Mai et al. 2012). Authors like Lee and Lam (2012) point out that technological resources and the improvement of IT systems for RL led to a more sustainable result for environmental protection, social responsibility, and economic performance, simultaneously. Sharma et al. (2022) and Sun et al. (2022) reinforce this findings with focus in the pharmaceutical industry.

The recent implementation of a system for dispensing medication at the pharmaceutical care process offered benefits like stock control and agility in the process of dispensing medication to users. Standard operating procedures (SOP10) were also developed, whereby managers were able to register medication that would be returned to the dispensary and/or collected for sanitary disposal using a stock management system. Statistical results show a strong relation between IT facilitating expiry monitoring activities and the separation of medication to be returned.

Another challenge faced by the public healthcare sector is the need to find specific outsourced companies to recycle and handle EOL products (Sivakumar et al. 2018). This ends up generating costs and, very often, difficulties in finding third-party logistics providers (3PLs), discouraging this practice (Prakash and Barua, 2015; Sivakumar et al. 2018).

Organizational managers must provide a suitable location to temporarily store products returned by end-users. Studies show that a lack of infrastructure may present a barrier to the RL implementation process (Kumar and Dixit, 2018; Massoud et al. 2015; Meyer et al. 2017; Prakash and Barua, 2015). For this study, infrastructure, formerly represented by physical aspects, reverse logistics, and reallocation, did not present statistical results that alter EOL-MP. As mentioned before, this may be explained by the fact that the current infrastructure is considered by interviewees sufficient for the current reverse flows of the system.

With regard to political aspects, as discussed by Pereira et al. (2017) and Aquino et al. (2018), there is still no sectoral agreement for the pharmaceutical industry that establishes mandatory relations among different links of the chain. The main attributes of a sectoral agreement would be general guidelines for public and private sector managers, with goals and specific actions to structure the reverse logistics system.

The results showed a strong relationship between political aspects in EOL-MP. Aquino et al. (2018) affirm that the planning of the municipal healthcare solid waste management document, based on RDC 222/2018 (Brazil, 2018), is an important mechanism to guide managers keen to support the correct disposal of waste generated through medical and hospital care.

Political direction concerning RL for healthcare waste from the pharmaceutical care network, including syringes, needles, and even medicine, already exists due to the national policy on solid waste (PNRS, Portuguese abbreviation) and RDC 222/2018 (Brazil, 2018). However, health professionals continue discussing forms of operationalization. This is a complex discussion as it involves the type of waste, a form of separation and disposal, need for professional capacity building, and infrastructure, both in-company and outsourced context.

With the institution of Federal Decree 10,388 (5th June 2020), the RL for end-of-life and end-of-use medication coming from the population should gain political strength. Consequently, it may influence the management of the pharmaceutical care network, in the sense of calling for adaptation within the public sector in the short term. This seeks to sway the old anxieties of the pharmaceutical sector, as well as concerns regarding care for the environment, especially at a time in which the world is dealing with a pandemic.

Concerning the political effect on inspection, despite the existence of decree, PNRS, and RDC, some elements complicate inspection efforts. The question is will ANVISA (Brazilian Health Surveillance Agency) have the available infrastructure and human resources to meet inspection demands?

Another aspect that should be highlighted lies in the financial and economic factor. Improvements could be made to the IT system, services should be outsourced, and in general, improvements could be made to separation and storage spaces, lastly, though primarily in role, dispensing medication and inputs among users of the Unified Health System (SUS, Portuguese acronym). These elements have had a major impact on EOL-MP, with the availability of financial resources also tending to result in considerable improvements to PCP infrastructure. A lack of financial resources was a barrier described by Abdulrahman et al. (2014). Finally, with regard to EOL-MP, it was noted that implementing reverse logistics practices

impacts PCP logistics performance, which converges with the findings presented by Morgan et al. (2016).

Ding et al. (2018) also highlighted that activities involving reverse logistics have a major impact on logistics performance. According to the results of this study, pharmacists from municipal pharmacies are aware that EOL-MP has a positive and direct impact on the control of medication and input expiry, on medication close to expiry, and also on medication not in stock.

## Theoretical implications

From a theoretical point of view, the study held with pharmaceutical care process pharmacists showed congruence concerning the influence of critical factors on the implementation of end-of-life management practices while interfering with logistics performance. From the practical point of view, public healthcare system managers must pay attention to critical factors so that they do not become barriers, further complicating the implementation of reverse logistics. The pharmaceutical care process is routine in all the 5000 municipalities of the country. Moreover, this operation mode from the Brazilian Health System (SUS) is a reference for other countries in South America and Europe.

Concerning the Brazilian scenario, the pharmaceutical care process managers should urgently discuss how to organize the cycle to facilitate the implementation of reverse logistics of EOL medicines returned from the population. Investment should be made to support the development of human resources on EOL-MP, new infrastructure implementation, including IT systems, or policies to facilitate the outsourcing of reverse logistics and circular economy efforts.

A discussion that parallels reverse logistics is the circular economy process, which has already shown promising results in developed nations. With the COVID-19 pandemic, issues related to direct and reverse logistics and especially the management of healthcare waste have gained broader theoretical and practical relevance, since there is a higher demand for solutions to the health waste generated by pandemics, coupled with the elevated potential to propagate diseases.

On the other hand, the theory of a resource-based view provides mechanisms and elements that guide managers of the supply chain in developing strategies to operationalize the pharmaceutical care process reverse logistics activities, establishing the necessary resources, core capacities, and operational routines.

## Key recommendations for policy formulators and professionals

Based on the analysis, we can provide some key recommendations for policymakers which are presented as follows.

- *Broad communication of the impact of critical factors on logistic performance*—Critical factors in the implementation of EOL management practices for medication must not be ignored by public healthcare sector managers, as they impact logistics performance.

It is imperative that critical factors in the implementation of EOL management practices for medication are not ignored by public healthcare sector managers, as they impact logistics performance; they must communicate and train professions to deal with critical factors, before they become barriers.

- *Investment in digital technologies*—the exploration of emerging industry 4.0 digital technologies may lead to intelligent and agile operations, facilitating the creation of sustainable value, in the sense that a sustainable pharmaceutical supply chain should extend to product operations and management in the reverse/circular cycles.
- *Urgent policies to cope with health waste*—the current COVID-19 pandemic provides solid evidence on how vital waste management is while also highlighting the many vulnerabilities of developing nations, such as Brazil.
- *Urgent policies to cope with return flows of medicine from the population*—after the institution of the medication reverse logistics decree, other policies must be formulated to guide government agencies. The agencies must be supported in their responsibility to provide solutions for the management of medicines returned by the population or returned from the public healthcare sector, which currently presents elevated potential to affect the environment and propagate diseases.

This study focused only on medicine waste, which already presents a high level of complexity for decision-makers. In the face of the COVID-19 pandemic, many other types of hazardous and infectious waste are generated around the world, such as personal protection equipment (PPE), masks, gloves, and other infected equipment. According to RDC 222/2018 (Brazil, 2018) classification, this type of waste is categorized as group A and subgroup A1, presenting biological risks (infectious). According to the United Nations Environment Program (UNEP) UNEP (2020), incorrect management of this waste may have irreversible effects on human health and the environment. As such, safe handling and correct final disposal of this material is vital to an effective urgent response.

As discussed by Sarkis et al. (2020), the current global crisis also provides opportunities to transform into a sustainable supply and production system, catalyzing the transition to sustainability and a circular economy post-pandemic. The importance of strengthening the articulation between the health sector and other health secretariats is also highlighted,

cooperating to promote the prevention and control of hospital waste, through a joint effort.

## Limitations

Some limitations apply to this study. The first concerns the sample size. The number of respondents is representative of the process analyzed and was adequate to provide statistically significant results. However, in future applications, other sample sizes should be investigated. These findings apply to specific regions of Brazil. Although the methodology may be applied in other regions or countries, specificities of the pharmaceutical care processes studied may lead to different results.

## Conclusions

Considering the resource-based view, this study aimed to assess the influence of critical factors in the adoption of end-of-life management practices for medication and to determine the effect on pharmaceutical care process logistics performance. Findings have contributed to the literature by providing deeper insights into the relationship existing between management factor and end-of-life management practices on logistics performance. Collaboration, information technology, politics, and financial and economic critical factors demonstrated to influence end-of-life management practices.

More than providing insights to local pharmaceutical care process managers on decision-making, this study reinforced previous findings from the literature on critical factors that affect reverse logistics. The authors also provided key recommendations to policymakers and professionals, concerning the reverse logistics of medicines in primary healthcare systems. The methodology may be applied to other contexts in Brazil and abroad, and a comparison of findings will lead to more insights.

With the sudden onset of the COVID-19 pandemic, the management of waste from the healthcare system has become an important issue. This is a very important opportunity to develop reverse logistics of medicines and health wastes on the way to the broader concept of the circular economy of pharmaceuticals. In future studies, more research is encouraged to discuss the transition towards a circular economy and look at how organization resilience can reduce the impacts of COVID-19, fostering collaborative efforts in efficient healthcare waste management.

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**Data availability** All data used are presented in the body of the text, and the questionnaire used can be accessed as a complementary document.

## Declarations

**Ethics approval and consent to participate** This study was approved by the Research Ethics Committee, the Federal University of Rio Grande do Sul, and Municipal Health Department under number CAAE 82571018.6.0000.5347 and opinion no. 3.272.380. It was conducted in the Pharmaceutical Care Process (PCP) cycle that is under the Pharmaceutical Assistance Coordination (PAC) in the City of Porto Alegre, Brazil.

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