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Redesigning Healthcare Procurement for Environmental Sustainability: A Delphi study across product categories and procurement models

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Abstract

Healthcare systems are increasingly required to integrate environmental sustainability into procurement practices, yet existing procurement models often struggle to operationalise sustainability objectives across different healthcare product categories. This thesis investigates how healthcare procurement models can be redesigned to better align with environmental sustainability goals, considering the specific characteristics of medical devices, consumables, and pharmaceuticals.

The study adopts a two-round Delphi methodology combining qualitative exploration and quantitative prioritisation. Round 1 identified key motivations, sustainable and circular practices, limiting factors, and procurement redesign elements. Round 2 assessed their relevance and degree of consensus using both descriptive statistics (mean, median, Interquartile Range) and inferential statistic (Kendall's W coefficient of concordance). The findings reveal strong convergence among experts regarding the importance of integrating environmental sustainability into healthcare procurement, particularly in relation to environmental impact reduction, lifecycle cost considerations, and institutional responsibility. However, greater divergence emerges in the prioritisation and feasibility of specific sustainability practices, reflecting regulatory, organisational, and product-specific constraints.

Results show that sustainability drivers are largely shared across product categories, while feasible implementation pathways differ significantly. Medical devices and consumables offer greater scope for procurement-led sustainability intervention, particularly through supplier environmental assessment, and the progressive adoption of circular practices, albeit constrained by regulatory and risk-management considerations. In contrast, pharmaceutical procurement is more strongly shaped by regulatory frameworks and market standardisation, limiting the range of feasible sustainability interventions.

Overall, the study demonstrates that effective sustainability integration requires adaptive, context-sensitive procurement strategies that jointly consider product characteristics, procurement models, and organisational capabilities. By moving beyond aggregate interpretations of sustainable healthcare procurement, this research contributes to a more differentiated understanding of how sustainability objectives can be translated into operational procurement

practices and provides expert-informed guidelines to support sustainability-oriented procurement redesign.

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List of acronyms

CE	Circular Economy
CH₄	Methane
CO₂	Carbon dioxide
CPV	Common Procurement Vocabulary
EMA	European Medicine Agency
EMAS	Eco-Management and Audit Scheme
ESG	Environmental, Social, and Governance
GHG	Greenhouse Gas
GHGP	Greenhouse Gas Protocol
GP	Green Procurement
GPP	Green Public Procurement
HTA	Health Technology Assessment
IQR	Interquartile Range
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
MRI	Magnetic Resonance Imaging
N₂O	Nitrous Oxide
OEM	Original Equipment Manufacturer
PPE	Personal Protective Equipment
Q1	First quartile
Q3	Third quartile
ROI	Return on Investment
SBTi	Science-Based Target initiatives
SDG	Sustainable Development Goals
SP	Sustainable Procurement
TCO	Total Cost of Ownership
WHO	World Health Organization
ASL	Azienda Sanitaria Locale
AOU	Azienda Ospedaliero-Universitaria

1. Introduction

1.1 Context and relevance of environmental sustainability in healthcare procurement

The healthcare sector is essential for safeguarding public health, but it is also a significant contributor to the environmental degradation, being highly energy and resource intensive, and accounting for more than 4% of global greenhouse gas (GHG) emissions (Leal Filho et al., 2024; McGain et al., 2017). This environmental footprint is a critical issue and is pushing policymakers, healthcare professionals, and researchers to reconsider how high-quality patient care can be delivered in harmony with environmentally responsible practices (Sherman et al., 2020).

Sustainability can be conceptualized within the concept of the triple bottom line, which entails the simultaneous consideration of the economic, environmental, and social effects of business activities. In particular, in the healthcare sector, procurement can play a pivotal role in integrating sustainability, since the way in which healthcare product categories, such as medical devices, consumables, and pharmaceuticals, are procured directly impacts on energy consumption, GHG emissions, and waste generation (Ahmed et al., 2021; Souza et al., 2025). Moreover, traditional procurement models are often focused solely on cost-efficiency and clinical performance, proving to be inadequate to address environmental issues. This makes the introduction of a new approach to procurement, aimed at long-term environmental value creation, increasingly necessary (Zaidi et al., 2021; Ahsan et al., 2022).

Various frameworks and policy initiatives have been introduced to support the shift toward more sustainable practices, such as the Eco-Management and Audit Scheme (EMAS) Regulation (EC No. 1221/2009) which provides guidance on how to integrate environmental criteria into public procurement processes, or the European Green Deal and the Sustainable Development Goals (SDGs) which underline the strategic role of green public procurement (GPP) in achieving carbon neutrality. In the healthcare sector, instead, specific strategies, such as the implementation of criteria for low-carbon or zero-emissions procurement (Wilburn, Jharia and Prabhakaran, 2021; Lavoie et al., 2024), are being implemented to better align procurement decisions with environmental sustainability goals. Nonetheless, moving toward sustainable

procurement remains a complex task as healthcare systems often face structural and cultural barriers. These, in addition to financial constraints and the need to provide fast and effective medical treatments, may hinder innovation in procurement practices (Etse, McMurray and Muenjohn, 2021; Pinzone, Lettieri and Masella, 2015; Verdonck and Verniers, 2024). On the other hand, a growing body of research highlights promising directions, such as the development of digital tools, the adoption of green and circular economy practices, and the setting of carbon-reduction targets that could reshape healthcare procurement making it more environmentally sustainable (Soni and Yadav, 2022; Olawade et al., 2025). For instance, departments like anaesthesiology and dermatology are beginning to introduce green and circular procurement practices, demonstrating that leadership commitment and system-wide coordination are essential to scale up these initiatives and institutionalize sustainability as a procurement norm (Ali, Wernham and Abbott, 2025; McGain et al., 2017).

1.2 Research objectives

The overall goal of this thesis is to investigate how current healthcare procurement models can be redesigned to align with environmental sustainability objectives across different product categories, namely medical devices, consumables, and pharmaceuticals. To achieve this goal, three main research objectives are pursued:

1. To map the specific practices and barriers associated with green and circular procurement of healthcare product categories: medical devices, consumables, and pharmaceuticals.
2. To identify the procurement models predominantly employed in the healthcare sector and to assess their limitations in addressing environmental sustainability goals.
3. To develop practical guidelines for modifying procurement models to better support environmental sustainability goals and to incorporate circular procurement practices, tailored to the unique characteristics of medical devices, consumables, and pharmaceuticals

1.3 Contribution of the work and structure of the thesis

Although previous research has tended to focus on sustainable procurement in healthcare through broad, system-level analyses, there is still limited insight into the specific barrier and

practices that characterize the green and circular procurement across different healthcare product categories: medical devices, consumables, and pharmaceuticals (Sanderson et al., 2015).

This thesis contributes to the topic by adopting a category-specific approach, offering a deeper understanding of sustainability challenges and opportunities across the three product categories. Additional contribution lies in the empirical method employed: a three round Delphi study involving procurement professionals from the healthcare sector. This method enables the collection of expert opinions and facilitates consensus-building around key barriers and practices on green and circular procurement, and limits of current procurement models, fostering the development of practical guidelines for redesigning procurement models to better align with environmental sustainability goals.

To support this contribution, the thesis is structured as follow:

- Chapter 2 presents a review of the literature to explain the basic concepts about healthcare procurement and environmental sustainability goals, followed by a focus on specific environmental issues and opportunities of medical devices, consumables, and pharmaceuticals
- Chapter 3 outlines the methodology used to collect and analyse data
- Chapter 4 presents the results of the Delphi rounds, including both qualitative and quantitative analysis of expert opinions for consensus-building across the rounds
- Chapter 5 offers a summary of the findings, discussing also their academic and practical implications and the limitations of the work

2. Literature Review

The review sets the foundation for understanding the conceptual and practical challenges of implementing sustainable and circular procurement in healthcare, leading to the refinement of the research question and objectives of this thesis. Firstly, procurement is defined and presented with an outline of the main processes and actors, before providing an overview of current healthcare procurement models (Section 2.1). Next, the main environmental sustainability goals relevant for healthcare are identified, considering national and international regulations (Section 2.2). Then, approaches to sustainable procurement are analysed, considering both green and circular procurement practices and discussing how they can be applied in the healthcare setting (Section 2.3). After that, the healthcare product categories, considered in this study, are presented together with the specific environmental issues and opportunities associated with them (Section 2.4). Based on this, the limitations of current procurement models are identified (Section 2.5), before presenting the research gaps (Section 2.6) and the research question (Section 2.7).

2.1 Healthcare procurement definition and functions

Healthcare procurement is defined as the process of managing all activities associated with the purchase of goods and services required to operate an organization (Hinrichs et al., 2014). This includes all the actions of planning and forecasting, identification of needs, sourcing and solicitation of offers, evaluation of offers, review and award of contracts, contracting, and the end of the useful life of an asset (WHO, 2011). Unlike other sectors, healthcare procurement directly influences human health and environmental sustainability: this is why it operates within a highly regulated framework ensuring safety, transparency and legal compliance (WHO, 2025). Furthermore, the technical complexity of healthcare product categories, such as medical devices, and pharmaceuticals, increasingly requires the employment of expert professionals and technologies, such as the Health Technology Assessment (HTA), which can support the decision-making processes, finding a balance between sustainable innovation and cost-efficiency (Callea et al., 2017; Salvatore, Boscolo and Tarricone, 2013). Subsections 2.1.1 and 2.1.2 will outline the main steps and actors involved in the procurement processes and the main healthcare procurement models.

2.1.1 Main procurement stages and actors

While frameworks can slightly vary depending on factors such as geographical location or the specific organization, the main phases of a procurement process can be described as:

- Needs identification: this step is needed to ascertain and define the organization's needs. In the healthcare industry, this entails the identification of needs to support clinical or operational functions (Grandia and Volker, 2023)
- Planning: it allows to develop procurement plans that align the procurement needs with budgetary constraints and objectives. In the healthcare industry, these goals include primarily the expected clinical outcomes, while additional goals may include sustainability and innovation (Stek and Belotti, 2025)
- Specification development: it is a complex process that involves the collaboration of experts from various departments and engineers. Experts formulate technical and functional requirements, which are subsequently used as the basis for the evaluation of suppliers and, within the healthcare industry, for the assurance that the products meet both clinical and regulatory standards (Göncü and Çetin, 2022)
- Market analysis: this process involves the collection and interpretation of data related to the dynamics of the market. It entails conducting market research to identify potential suppliers, considering factors such as availability, reliability and compliance with relevant healthcare regulations (Cordell and Thompson, 2019)
- Supplier selection: competitive tenders or private negotiations are the predominant methods employed to select a supplier. In the healthcare industry, the evaluation is based on the medical, functional and technical requirements, such as quality properties, ergonomic properties of the equipment, functionality and it may include environmental properties. In addition, the total cost of the investment is calculated (Terio, 2010)
- Contracting: upon selection of the supplier, the procurement agreement is finalized by detailing the contractual terms, including delivery schedules, warranties, and compliance obligations, with the objective of preventing supplier's opportunistic behaviours (Sanderson et al., 2015). In public procurement, the introduction of digital technologies can provide governments with improved data processing capabilities, enhancing transaction efficiency and supporting better risk management in the contract execution and payment phases (OECD, 2025)

- Delivery: delivered products are inspected by the healthcare organization in order to ensure conformity with specified requirements. Payment to the supplier is only issued once the inspection process is completed (Dimitri, Piga and Spagnolo, 2006)
- Evaluation and performance monitoring: these activities are conducted during the utilization of the products to assess the performance of the supplier, the adherence to contractual terms, the product effectiveness, and the overall success of the procurement strategy. The primary objective of monitoring is the collection of data for future procurement (WHO, 2011).

Figure 1 illustrates the sequence of the described procurement stages.



Figure 1- Schematic illustration of the procurement process (adapted from Terio, 2010)

Another significant aspect of the procurement process is the identification of the key actors involved in each phase. The multidisciplinary engagement is crucial to ensure that procurement decisions align not only with clinical needs, but also with economic efficiency, legal compliance, long-term value generation and environmental sustainability (Salvatore, Boscolo and Taricone, 2013). The mapping of the involvement of these actors across the various stages is important to highlight the necessity of communication and coordination to ensure the success of the overall procurement process.

Due to the technical complexity of the healthcare sector, procurement professionals must collaborate with stakeholders from various disciplines, including legal, administrative, clinical, logistic, technical, and institutional domains. These stakeholders can provide critical inputs during phases as specification development, contracting, and product and supplier evaluation

process (Stek and Belotti, 2025). The involvement of experts is not uniform across all phases but rather varies depending on the nature of the good being procured, the procurement method, and the organisational structure. However, synthesising insights from the literature and practical guidelines, Table 1 presents the main stakeholder categories and their contribution to the procurement process.

Table 1- Stakeholders involved in healthcare procurement

Stakeholder category	Stakeholder	Contribution to the procurement process	Source(s)
Administrative	Procurement office	Oversight of the entire procurement process, with a focus on ensuring procedural compliance, effective cost management, fulfilment of deadlines, and coordination of stakeholders	(Stek and Belotti, 2025)
	Financial office	Monitor the financial sustainability of the organization and validate the budget	(Hinrichs et al., 2014)
Legal	Legal and Compliance office	Ensure that the procurement process is compliant with national and international laws, draft and validate contracts with suppliers	(Dimitri, Piga and Spagnolo, 2006)
Technical	Biomedical engineers/ Technical experts	Translate clinical needs into technical specifications and evaluate the functionality and compatibility of products	(Hinrichs et al., 2014; Terio, 2010)

Table 1 (continue)

Stakeholder category	Stakeholder	Contribution to the procurement process	Source(s)
Technical	IT specialists	Provide specifications concerning the digital systems, ensuring the compatibility with existing devices and compliance with data protection and cybersecurity standards	(Hinrichs et al., 2014; WHO, 2011)
Logistic	Supply Chain Managers	Ensure the timely and traceable delivery of products, monitor storage conditions and support in the evaluation of supplier performance	(WHO, 2011; Sanderson et al., 2015)
Clinical	Doctors, nurses	Identify clinical needs to define performance and safety requirements, and assess clinical suitability of the solutions	(Callea et al., 2017; Salvatore, Boscolo and Tarricone, 2013)
	Pharmacists	Identify pharmaceuticals needs, and drug-related specifications, ensuring the alignment with the established therapeutic protocols	(Sanderson et al., 2015)
Institutional	Central purchasing body	Manage centralized procurement activities, negotiate agreements and provide data about suppliers	(WHO, 2025)
	National and international authorities	Define procurement guidelines, allocate budgets and establish health and sustainability priorities	(Hinrichs et al., 2014; WHO, 2025)

2.1.2 Overview of current procurement models in healthcare

A procurement model refers to the set of practices that govern how an organization plans, manages, and executes its procurement activities. It includes the processes, roles of various stakeholders, decision-making criteria, sourcing strategies, and supplier relationships involved in procuring goods and services (Cordell and Thompson, 2019). Different models differ in terms of degree of centralization, procurement mechanisms, and the extent to which they incorporate strategic and sustainable objectives.

Centralized procurement, also known as group procurement or collaborative procurement, is characterized by a single organization, often the Government or a central purchasing body, who manages procurement on the behalf of multiple organizations (Callea et al., 2017). Centralized procurement can be implemented at national, regional or local level, depending on the governance structure, market size, and regulatory autonomy. This model consolidates demand across multiple organizations, enabling bulk ordering, reduced logistic complexity and streamlined contracting, leading to reduced unit costs and the transaction costs related to administrative overheads or inefficient invoicing. Such consolidation of demand can be also implemented through pooled procurement, in which multiple organizations combine their procurement power to achieve better prices, reduce information asymmetries, and improve access to essential products (Dimitri, Piga and Spagnolo, 2006). However, disadvantages include reduced responsiveness to the specific need of individual organizations (Grandia and Volker, 2023). Furthermore, centralized procurement can exacerbate shortages when only one supplier is selected and fails to fulfil the contract, discouraging non-winning manufacturers from remaining in the market and this could be especially problematic for essential products like pharmaceuticals (Wilsdon et al., 2020).

On the other hand, procurement is decentralized when individual organizations autonomously decide when, what and how to procure goods and services. They directly negotiate with suppliers, often preferring local vendors which may not always be cost-effective. In fact, this model is characterized by lower transparency and a higher risk of errors due to incorrect or incomplete information sharing (Dimitri, Piga and Spagnolo, 2006). While decentralization allows greater flexibility and responsiveness, it requires higher procurement competencies within each organization and does not benefit from economies of scale (Grandia and Volker, 2023).

Lastly, hybrid procurement models lie in between full centralization and full autonomy, sharing power on procurement decisions between the central and local purchasing bodies. An example of hybrid procurement is the centre-led procurement model, where strategic decisions are taken centrally, while transactional activities are executed locally (Dimitri, Piga and Spagnolo, 2006). Although not yet widespread in healthcare, these models are gaining popularity in order to overcome the disadvantages of both the centralized and decentralized procurement models, achieving both economies of scale and high responsiveness to local needs (Kastanioti et al., 2013; Grandia and Volker, 2023).

In recent years, e-procurement, intended as the use of electronic data interchange and web-based biddings (WHO, 2011), has emerged to enhance the efficiency and the transparency of procurement processes. Furthermore, recent innovations include the integration of predictive analysis and artificial intelligence into centralized procurement models, especially for pharmaceuticals, allowing forecasting of demand, optimization of inventory, and prevention of shortages. For example, a regional group purchasing organization consisting of six hospitals using Machine Learning-based demand forecasting showed a stockout rate for high-risk injectable medications below 2%, improving also health outcomes (Anthony et al., 2025). Figure 2 summarizes the main procurement models and highlights how e-procurement and machine learning can be applied across all of them to enhance efficiency and transparency.

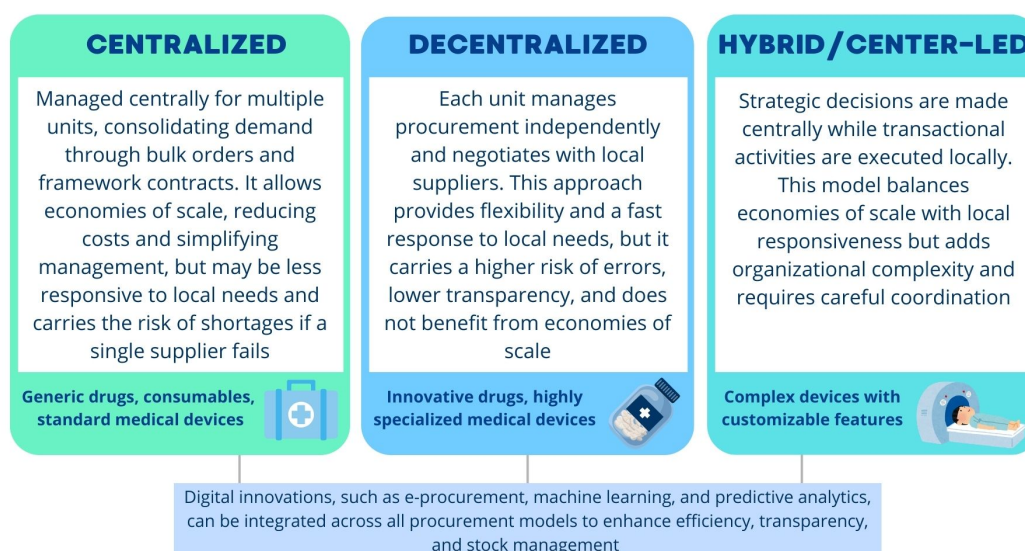


Figure 2- Healthcare procurement models: key features, advantages, and disadvantages

Procurement models are differently applied depending on the healthcare product category. Centralized procurement is widely used in pharmaceutical procurement, especially for generic drugs. In fact, pharmaceutical purchase account for the largest healthcare costs in any country

in the world, varying from 5% to 12% in developed countries and up to 40% in developing countries (Boche, Mulugeta and Gudeta, 2022). In such context, competitive biddings can lead to cost reductions of up to 15% compared to decentralized procurement (Dubois, Lefouili and Straub, 2021). Instead, for more innovative drugs not covered by national healthcare systems or in emergency scenarios, such as local epidemics, decentralized procurement is still used, with individual organizations negotiating directly with suppliers (Nakambale and Bangalee, 2022; Boche, Mulugeta and Gudeta, 2022). Furthermore, pooled procurement or group purchasing organizations are particularly effective for essential drugs or vaccines, increasing bargaining power, reducing information asymmetries and enhancing access, especially in resource-constrained countries (Gianfredi et al., 2021).

Centralized procurement through framework agreements, instead, is common for consumables and some medical devices, while negotiated agreements are generally reserved for complex medical devices, such as diagnostic imaging systems or clinical software (Vogler, Bauer and Habimana, 2022). However, centralized or pooled procurement is less effective for very high-cost and highly specialized devices like cardiac stents or orthopaedic implants, where customization and hospital-specific requirements play a larger role (Callea et al., 2017). In these cases, the integration of HTA into the procurement process can help achieve a balance between cost-efficiency and innovation, leading to procurement decisions based not only on price, but also on value (Salvatore, Boscolo and Tarricone, 2013). Notably, in Italy, despite the wide use of centralized procurement for medical devices, dental devices constitute an exception being still acquired through decentralized procurement and primarily sold to private providers.

2.1.3 Procurement models in the Italiano healthcare system

The Italian healthcare system is characterised by a multi-level governance structure in which procurement activities can be carried out at national, regional or local level. While the central government defines the overall framework of the National Health Service, regions are responsible for organising healthcare services and procurement activities. In recent years, a gradual process of centralisation has taken place through the establishment of regional purchasing centres and the strengthening of the national purchasing body CONSIP, which provides framework agreements and electronic procurement tools such as the Mercato Elettronico della Pubblica Amministrazione (MEPA) (Baldi and Vannoni, 2014).

Based on this institutional structure, five main procurement models can be identified:

- National procurement through CONSIP and MEPA. CONSIP provides framework agreements and electronic procurement platforms available to public administrations, including healthcare organisations. These tools allow administrations to procure goods and services through pre-negotiated contracts or electronic marketplaces, improving efficiency and transparency (Baldi and Vannoni, 2014; Ferraresi, Gucciardi and Rizzo, 2021)
- Regional centralised procurement. Procurement is managed by a regional purchasing centre (Centrale di Committenza Regionale), which conducts tenders on behalf of healthcare organisations within the region. In many regions these purchasing centres play an increasingly important role in negotiating contracts and achieving economies of scale (Ferraresi, Gucciardi and Rizzo, 2021)
- Regional collaborative procurement. Multiple healthcare organisations jointly conduct procurement procedures, typically designating one organisation as the lead buyer. This allows partial demand aggregation while maintaining a degree of local autonomy and can be considered a hybrid form between centralised and decentralised procurement (Ferraresi, Gucciardi and Rizzo, 2021)
- Autonomous procurement. The procurement process is conducted independently by individual healthcare organisations through competitive tendering procedures. This approach corresponds to a decentralised procurement model in which organisations retain full decision-making autonomy regarding product specifications, supplier selection, and contract management, and allows high responsiveness to local clinical needs, although it may limit the potential benefit of demand aggregation (Baldi and Vannoni, 2014)
- Direct procurement. Procurement is carried out through direct award to a supplier without competitive tendering procedures and is typically used in specific situations allowed by procurement regulations, for example when products are highly specialised or when organisations have specific needs. While it allows rapid acquisition of good and services, it provides limited competition and transparency compared to competitive tendering procedures (Baldi and Vannoni, 2014)

2.2 Environmental sustainability in the healthcare sector

The healthcare sector has significant environmental impacts, which include GHG emissions, resource consumption, and waste generation. It is increasingly essential to address these

challenges by adopting clear environmental sustainability goals that guide organizational strategies and operational practices, with procurement that may play a key role in enabling the transition toward greener and more sustainable healthcare systems (Leal Filho et al., 2024). Subsections 2.2.1 and 2.2.2 will outline the most important environmental sustainability objectives for the healthcare sectors, allowing to understand how these goals can help redesign procurement models and practices.

2.2.1 Policy and legislative frameworks

Environmental sustainability is shaped by a set of global, regional and national policy frameworks that provide both legal obligations and practical guidance, pushing the healthcare systems and their management towards integrating environmental goals into their procurement practices. Net-zero procurement measures are of utmost importance for organizations to tackle climate change, in line with the Paris Agreement, which came into force in November 2016 and aims to keep the increase in the global average temperature well below 2°C above pre-industrial level with efforts to limit it to 1.5°C. Moreover, incorporating sustainability in healthcare can strengthen the link between high-level policy goals and operational procurement practices, helping to reach financial, environmental and strategic benefits for the organization (Wilburn, Jharia and Prabhakaran, 2021).

At the global level, the United Nations' Sustainable Development Goals (SDGs), a set of 17 goals introduced in 2015, are part of the agenda for sustainable development by 2030, with specific targets addressing the world's most important issues, including poverty, inequality, climate change, and environmental degradation (Lindstrom and Coronado-Garcia, 2020). Considering healthcare sector, the most relevant SDGs (Figure 3) are:

- SDG 3 which directly addresses the health sector objectives ensuring healthy lives and promoting well-being for all
- SDG 12 which emphasizes the role of sustainable procurement in reducing resource use and waste by promoting sustainable consumption and production patterns
- SDG 13 which calls for urgent measures to combat climate change and is linked to the initiatives of the Paris Agreement.



Figure 3 – The 17 SDGs of the 2030 Agenda with focus on SDG 3, SDG 12, and SDG 13

The World Health Organization (WHO) has developed health-specific frameworks linking climate and health, emphasizing that procurement decisions can significantly contribute to climate mitigation and resilience in healthcare systems (WHO, 2017). Similarly, recent studies have adapted the International Organization for Standardization (ISO) 20400 to address environmental, social and governance (ESG) dimensions of medical procurement, highlighting the operational steps and showing that proactive measures, such as conducting cost-benefit analysis, implementing change management strategies, and demand for sustainable alternative, will be required to overcome challenges faced by healthcare professionals in implementing sustainable procurement, such as regulatory compliance, financial constraints, resistance to change, and limited availability of sustainable products (Souza et al., 2025).

At the European level, the European Green Deal, launched in 2019, sets out a plan for climate neutrality by 2050, investing in innovation, clean technology, and green infrastructures. With instruments like the EU Climate Law and the Fit for 55 package, the Green Deal provides targets for 2030, which are expected to influence procurement regulations and funding mechanisms, including the healthcare sector. The EU Circular Economy Action Plan reinforces these goals by promoting reuse, repair, and recycling practices, thereby reducing pressure on natural resources. More specifically, public procurement offices are provided with specific tools and guidelines such as voluntary GPP criteria or the specific modules of the GPP Training Toolkit, including those focused on the Circular Economy (CE), which provide support in practical steps like defining environmental criteria, conducting lifecycle cost analyses, and integrating eco-labels or supplier certifications. For example, the Buying Green! Handbook serves as a practical manual for integrating environmental criteria into public tenders, offering examples directly

applicable to the healthcare context, such as the procurement of products designed to be resource-efficient and to facilitate reuse and recycling. Moreover, recent EU initiatives are considering the introduction of mandatory minimum GPP criteria in some sectoral legislation and reporting obligations to monitor uptake. Some experiences are already present in the healthcare sector: for instance, a case study from Norwegian municipalities described the alignment of consumables procurement with environmental criteria by requiring supply chain traceability, sustainable packaging, and low-impact logistics, and assessed the maturity of the market in meeting the demand of greener products (European Commission, 2021). This shows that, when properly designed, GPP may represent an environmental policy instrument able to conjugate environmental benefits and competitive improvement in firm performance (Testa et al., 2016).

In addition, the EMAS, a voluntary EU framework issued in 2009, provides organizations with a structured method for evaluating, reporting, and improving their environmental performance. It can support procurement functions in aligning practices with broader environmental management objectives, ensuring compliance with European environmental policy and fostering transparency through environmental statements. Despite the relevance of these frameworks, it is important to note that currently no binding sustainability policies are specifically tailored to the healthcare sector at either European or national level. Existing regulations and frameworks apply more broadly across industries, with healthcare included only as part of the wider scope (Lindstrom and Coronado-Garcia, 2020). This regulatory gap highlights that most progress in sustainability in the healthcare sector so far has been driven by voluntary initiatives, organizational strategies, and stakeholder engagement rather than sector-specific legislation (Lavoie et al., 2024). In particular, empirical studies have revealed that leadership engagement and stakeholder collaboration are critical enablers for achieving environmental sustainability goals in healthcare procurement (Chiarini and Vagnoni, 2016). In fact, today, leading organizations are the ones which were more able to integrate sustainability in their strategic plans, involving key stakeholders and being, consequently, less pressured by external policies and regulations (Gelderman, Semeijn and Vluggen, 2017a).

2.2.2 Environmental sustainability goals in healthcare

A sustainable healthcare system delivers high quality care without exhausting natural resources or causing environmental damage (Zaidi et al., 2021). Among the most important environmental goals in the healthcare sector is the reduction of GHG emissions, such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), measured as carbon dioxide equivalent (CO₂e)

(Olawade et al., 2025). Reducing GHG emissions involves multiple areas, including sustainable building design, and energy efficiency improvements through the adoption of renewable energy sources, alongside with supply chain and procurement optimization. Climate-resilient, low carbon health systems can anticipate and adapt to climate-related shocks, while minimizing GHG emissions and other environmental harms, thus protecting health now and for future generations (Huang et al., 2024; Olawade et al., 2025). According to the Greenhouse Gas Protocol (GHGP), healthcare emissions are classified into three scopes: scope 1 and 2 emissions account for 29% of emissions and can be reduced implementing energy efficient technologies and shifting to green infrastructures, while scope 3 emissions, accounting for 71%, mainly come from the improper disposal of hazardous and infectious materials, the large quantities of water used for patient care, sterilization and cleaning, and the manufacture of medical devices, consumables and pharmaceuticals, all of which require a large amount of raw materials and energy, further highlighting the crucial role of procurement decisions in reducing environmental impacts (Verdonck and Verniers, 2024; Leal Filho et al., 2024).

Waste management presents another key environmental challenge. The generation of healthcare waste, often classified as hazardous or non-recyclable, has increased notably after the COVID-19 pandemic. Single-use plastic, especially packaging, contributes significantly to landfill due to low recycling rates driven by economic factors, difficulty in separating materials and inadequate labelling (Leissner and Ryan-Fogarty, 2019). Additionally, considering that between 15% and 25% of the total healthcare waste contains radiological, biological or chemical hazard, ineffective waste management poses serious health and environmental risks, including the spread of infectious diseases, pollution, and contamination of water, air, and soil (Ertz and Patrick, 2020; Kanokphanvanich, Rattanawong and Vongmanee, 2023). Therefore, reducing the amount of plastic and polluting materials can represent also an opportunity to reduce costs for the organization. For example, life cycle assessments of different custom packs showed that cotton and other materials like polypropylene present high levels of GHG emissions, and that reducing unnecessary materials along with laundering of cotton towels resulted in lower emissions, waste generation and costs (Campion et al., 2015).

Given the high resource consumption and waste generation associated with healthcare operations, particularly in energy, water, and material use, many studies have highlighted the need to adopt circular economy principles of reducing, reusing, and recycling, instead of landfill or incineration, to mitigate environmental impacts and enhance cost-efficiency. The CE focuses

on greening the supply chain by improving resource and energy efficiency, reducing material consumption and optimizing processes to minimize the depletion of natural resources and address issues such as climate change and biodiversity loss (Kharat et al., 2025b). Particularly, the promotion of circular models that extend product lifecycle or redesign medical equipment to facilitate recovery and regeneration, reducing the dependence on virgin materials, can deliver both economic and operational benefits, limiting excessive consumables and packaging use (Zaidi et al., 2021). Transitioning from single use to reusable devices offers potential emission reductions and economic benefits due to extended equipment lifetime, though sterilization methods and water consumption may offset some advantages (McGain et al., 2017; Lingegård, Martin and Gheitasi, 2025).

Lastly, energy consumption and water conservation also have their importance. The first plays a pivotal role, with healthcare facilities increasingly pursuing energy efficiency to lower both costs and environmental impacts. As illustrated in Figure 4, energy efficiency, can be reached by using renewable energy sources to reduce the use of fossil fuels and decrease the carbon footprint of human activities (Kanokphanvanich, Rattanawong and Vongmanee, 2023). Also, replacing equipment with more efficient alternatives and adopting digital technologies for energy management are improvements that should be taken into consideration (De Waele et al., 2024). Water, on the other hand, is extensively used in hospitals for sterilizations, air-conditioning, and sanitization. Therefore, its conservation is essential, and a possible improvement is the recycling of water from sterilization, dialysis, and other processes for non-potable uses (Duque-Urbe, Sarache and Gutiérrez, 2019).

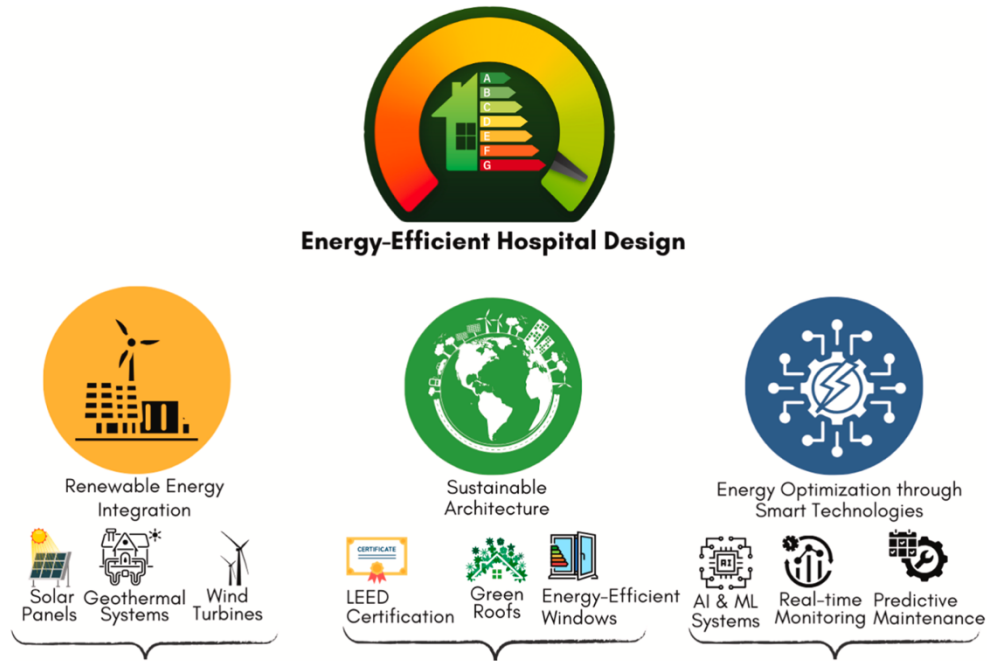


Figure 4 – Key component of energy-efficient hospital design (Olawade et al., 2025)

In summary, the priority environmental goals in healthcare are:

- Reducing carbon emissions
- Sustainable waste management and minimization of single-use plastics
- Improving energy efficiency
- Efficient resource usage, supported by transitioning to circular economy models and optimizing supply chain and procurement
- Water conservation and efficient usage

Regarding procurement, the integration of technical specifications related to environmental and climate performance of a product, and environmental award criteria into public and private procurement processes are key drivers to achieve these goals, allowing organizations to balance environmental concerns with costs and other factors (European Commission, 2016). Moreover, sustainable procurement policies, together with a shift in customer preferences, may influence demand for greener product, encouraging both suppliers to innovate, taking practical actions to reduce emissions and resource consumption and increase transparency, and the healthcare sector to develop specific sustainability metrics, adopting proactive environmental strategies (Pinzone, Lettieri and Masella, 2015; Wen and Liu, 2023). For instance, a Canadian study has demonstrated that firms setting targets through the Science-Based Targets initiative (SBTi)

reduced their GHG emissions by approximately 5% and their carbon intensity by 8-10%, in 2022 (Lavoie et al., 2024).

2.3 Approaches to sustainable procurement in healthcare

Sustainable Procurement (SP) entails the integration of environmental, social and economic considerations into procurement decisions to meet organizational needs for goods and services, while generating benefits and considering factors other than cost and quality (Gelderman, Semmeijn and Vluggen, 2017a). This procurement approach is consistent with the principles of the SDGs of ensuring a strong, health, and just society, living within environmental limits, and promoting good governance (Walker and Brammer, 2009). In the healthcare sectors, decision-making is often dominated by patient care priorities and clinical preferences for specific products, however SP is relevant due to the sector's high energy and resource consumptions and the complexity of its supply chain. Particularly, green procurement aims to minimize environmental impacts of products throughout their lifecycle, while circular procurement focuses on closing material loops and extending product lifecycles (Cheng et al., 2018). Subsections 2.3.1 and 2.3.2 will examine these two approaches in detail, analysing their applicability in the healthcare sector.

2.3.1 Green Procurement

The production, delivery, and disposal of goods and services acquired by healthcare facilities account for about 70% of healthcare emissions (Olawade et al., 2025). Green procurement (GP), also known as environmentally responsible procurement or eco-procurement, integrates environmental considerations into procurement decisions with the aim of minimizing the environmental footprint throughout a product's lifecycle. This includes reducing GHG emissions, improving energy and water efficiency, supporting recycling, and lowering resource use.

Over time, GP has gained increasing relevance in organizational and governmental strategies, seeking to align procurement practices with environmental objectives (Gelderman, Semmeijn and Vluggen, 2017b). In public procurement, which represents a considerable share of government expenditure in both developed and developing countries, GPP is an important tool to achieve environmental policy goals related to climate change, resource use, and sustainable consumption and production (European Commission, 2016). Moving toward products whose manufacture, use and disposal limit the negative environmental impacts, not only has direct environmental benefits, but also sends a strong message to suppliers and producers. Moreover,

regulations such as the European Directive 2004/18 have enabled purchasing bodies to include “green goals” in the definition of procurement strategies and in the contract award criteria (Dimitri, Piga and Spagnolo, 2006). Successful GPP implementation requires strategic planning, including determining the scope for green initiatives, setting measurable targets, providing staff training and establishing systems for performance monitoring (European Commission, 2016). GP can be embedded in multiple procurement stages: in the planning stage, environmental technical specifications and supplier selection criteria can be established; in the sourcing phase, presence of certifications, compliance with voluntary environmental standards and supplier’s environmental practices can be evaluated; during the contract phase, clauses can be added to address performance standards, evaluation procedures, and consequences for non-compliance (Rathi et al., 2013).

In healthcare, environmentally preferable procurement initiatives date back to the late 1990s. Although they were mainly focused on local environmental risks rather than global challenges such as climate change, they were able to raise awareness among providers and policy makers about the sector’s environmental footprint (Rathi et al., 2013). The sector’s high energy consumption, extensive use of single-use materials, and complex supply chains make GP particularly relevant. Minimizing the environmental impact of healthcare activities involves adopting product specifications and supplier selection criteria that prioritize reduced hazardous substances, energy efficiency, and minimal packaging usage, allowing to achieve superior outcomes while preventing undesirable consequences (Sherman et al., 2020; Soares et al., 2023). Examples include the procurement of energy-efficient imaging equipment, low-toxicity cleaning agents, sustainably sourced personal protective equipment (PPE), and the substitution of hazardous materials (e.g., heavy metals, chemicals containing reproductive and endocrine hazards, carcinogens) in medical equipment (Rathi et al., 2013).

However, a successful adoption depends on multiple drivers and is constrained by several barriers. Key drivers include compliance with environmental regulations, avoiding penalties and fines, top management support, customer demand and potential cost savings through resource efficiency (Giunipero, Hooker and Denslow, 2012; Walker and Brammer, 2009). Conversely, common barriers include limited technical expertise, inadequate supplier knowledge of green products or willingness to collaborate, lack of financial support, and unavailability of product alternatives that meet stringent healthcare quality standards while showing superior environmental performance (Kaiser, Eagan and Shaner, 2001). Moreover, the lack of green

procurement standards and the perception of higher costs further hinder the adoption (Olawade et al., 2025). Without appropriate tools, professionals have not enough knowledge to evaluate the overall cost and the return on investment (ROI) of green procurement, weakening the senior management commitment, who tends to implement only the practices which are imposed by national and international regulations. In these cases, tools such as the Life Cycle Assessment (LCA) and the Total Cost of Ownership (TCO) can make clear the convenience of green product for all stakeholders, considering their entire lifecycle, from raw material extraction to use and end-of-life disposal (Oruezabala and Rico, 2012; Giunipero, Hooker and Denslow, 2012). Organizational culture and management commitment in implementing sustainable practices are also lacking, leading to small budgets allocated to this purpose, lack of training and incentives which in turn reduces procurement staff's commitment to the procurement of green products. This also discourages suppliers from investing green products, resulting in a scarce availability of them on the market (Zaidi et al., 2021).

In practice, successful implementation depends, among the others, on policy frameworks and supplier readiness, as well as, on training procurement professionals to understand green procurement issues and express environmental preferences in procurement processes (Ahsan and Rahman, 2017). In some cases, prioritizing local supplier can reduce the emissions related to transport and build stakeholders' trust, although local supplier capacity to cope with demand or product availability may be limited. This can also support global policy goals such as SDG 12 - Responsible Consumption and Production and SDG 17 - Partnership for the Goals (Debnath et al., 2023). Therefore, GP represents a critical strategy for embedding environmental sustainability into healthcare procurement, significantly reducing the carbon footprint of healthcare operations, and stimulating supplier innovation (Cheng et al., 2018). However, overcoming institutional, market, and capability barriers remains essential.

2.3.2 Circular Procurement

Circular procurement refers to the acquisition of goods and services in a way that keep products, components, and materials in use for as long as possible, thereby reducing waste and resource extraction, and enabling organizations to embed circularity into procurement decisions and engage suppliers in partnerships that foster long-term sustainability (Guzzo et al., 2020). Unlike green procurement, which primarily focuses on reducing environmental impact during production and use phases, circular procurement emphasises closing material loops and extending product lifecycles. This shift implies that procurement decisions are not only evaluated based

on energy efficiency or toxicity, but also on reparability, modularity, take-back schemes and recovery processes for defective or expired products (Alfina et al., 2025).

The circular economy encompasses a range of restorative and regenerative strategies that go beyond traditional “end-of-life” concept, including refusal, redesign, reduce, reuse, repair, refurbishment, remanufacture, repurpose, recycle and recover (Kirchherr, Reike and Hekkert, 2017; Noort, Snijder and Weiland, 2025). As a guiding principle (Figure 5), strategies should prioritize options higher in the 9R hierarchy, which promote more efficient product design and use, extend useful life and reduce dependence on virgin materials. These approaches progressively decrease the system linearity and strengthen circularity. In this perspective, reuse should be prioritized over recycling, which remains a partial and less effective solution, especially for plastics (Gamba, Napierska and Zotinca, 2021).

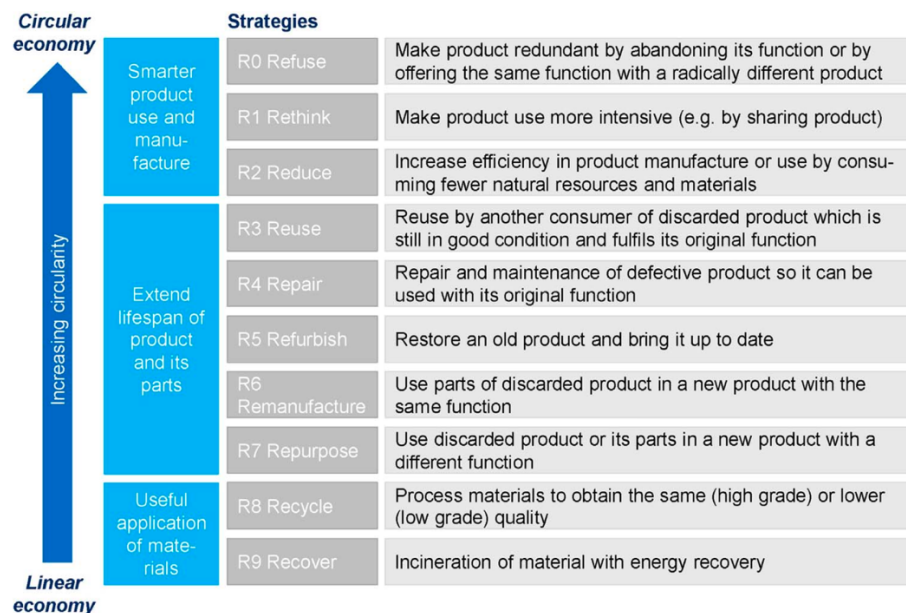


Figure 5 - The 9R Framework (Kirchherr, Reike and Hekkert, 2017)

Therefore, by adopting these strategies, healthcare organizations can achieve several benefits (Sgamaro et al., 2025):

- Reduce waste and resource usage by adopting reusable or recyclable medical equipment, conserving natural resources
- Prolong the lifespan of products through maintenance, repair, and refurbishment, reducing waste and disposal costs

- Enhance infectious and not-infectious medical waste management by implementing segregation and recycling, lowering both environmental pollution and medical waste disposal costs

In the procurement context, circular procurement requires integrating these strategies into tender specifications, supplier selection, and performance monitoring (Gamba and Olivan, 2019). This entails the introduction of collaboration between the procurer and the potential supplier, with a shift from rigid technical requirement to more collaborative discussions, thus introducing a change in value proposition from single ownership to continuous service provision, incentivizing suppliers to design durable and easily repairable products. (Guzzo et al., 2020; Witjes and Lozano, 2016).

Several circular business models have been proposed for healthcare such as leasing arrangements, product-service systems, hospital-based reprocessing, short term renting schemes for high-value equipment with fluctuating demand, platforms for products circulation, refurbished systems, and end-of-life collection programs. These models not only extend product lifecycles but also make reprocessing more appealing in terms of costs, promoting the transition from single use to reusable equipment (Guzzo et al., 2020). To support their adoption, circular maturity models have been proposed as roadmaps for healthcare organizations highlighting the importance of training programs for procurement professionals and enhancing the collaboration with suppliers, aligning procurement policies with broader organizational strategies (Sgambaro et al., 2025).

Design choices directly affect the feasibility of circular procurement. “Design for reuse” and “design for disassembly” allow modular configurations where critical parts (e.g. those in contact with patients) can be sterilized individually, while non-critical components can be reused more easily (Hossain, Ghose and Sahajwalla, 2025). However, regulatory and safety constraints may limit flexibility: redesigning medical products can introduce risk to patient health, making compliance with safety standards essential (Kane, Bakker and Balkenende, 2018). For this reason, procurement teams must collaborate with suppliers and designers to balance compliance with safety standards and circularity. Also, early integration of circular principles during the design stage allows to optimize resource use, durability and end-of-life recovery (Hoveling et al., 2024).

In the monitoring phase, to translate circularity into measurable outcomes, context-specific circularity indicators are required to the procurement teams. Proposed performance indicators include material recovery rate, extended product responsibility rate, and design alignment with circular economy principles (Alfina et al., 2025). Focusing on plastic-based products, measures such as recycled content, ease of disassembly, and whole-life-costing for comparison with single-use items are particularly relevant (Matschewsky, Lingegård and Martin, 2024). In pharmaceuticals, return rates of expired medicines and recyclability of packaging materials have to be considered as well to improve reverse logistic systems for the safe collection of expired or unused medicines, which involves the handling of hazardous products containing high-level chemicals that pose environmental and health risks if not managed properly (Kharat et al., 2025b).

Case studies further demonstrate the feasibility of circular approaches. For instance, reusable trocar systems, demonstrated measurable reductions in both environmental impacts and TCO, with benefits mainly obtained from the extensive reuse of trocars (Lingegård, Martin and Gheitasi, 2025). At the material level, opportunities for reintroducing high-value materials from discarded devices and consumables have been reviewed, emphasizing the need for improved reverse logistics and supplier collaboration. Although challenges remain especially for plastics, which dominate the healthcare sector but are difficult to recycle, design improvements, such as use of mono-materials, chemically compatible plastics, or easily recyclable polymers, can allow to reduce reliance on incinerators, which are still the primary form of material recovery, but also highly polluting, contributing to degrade the environment (Hossain, Ghose and Sahajwalla, 2025). Procurement policies can also extend product lifecycles by stipulating minimum durability guarantees, requiring maintenance services, and facilitating the redistribution of pre-owned components or parts of medical products (Ertz and Patrick, 2020b). However, persistent barriers hinder the adoption. These include high initial costs, lack of infrastructure for reverse logistics and sterilization, and perceived infection risks among healthcare staff (Saha, Farhanj and Kumar, 2025; Torkki et al., 2024).

Lastly, in the contractual phase, recommendations include linking award criteria to circular criteria, such as take-back obligations or performance-based payments linked to material recovery rates, also integrating maturity assessments into the supplier selection process, ensuring that contracted partners have both the capacity and the incentive to deliver circular solutions. This requires ongoing monitoring and collaboration, with periodic reviews to adapt criteria as

technologies and regulatory frameworks evolve and ensuring that the strategies adopted by suppliers are able to break linear patterns and mitigate supply constraints (Alfina et al., 2025).

2.4 Product categories in healthcare procurement: environmental issues and opportunities

Healthcare procurement encompasses a wide range of products. In this thesis, healthcare products are categorized into three broad categories: medical devices, consumables, and pharmaceutical. This categorization is aligned with the European Common Procurement Vocabulary (CPV), which provides a standardized framework for identifying goods and services in public procurement. The CPV includes distinct codes for medical devices (e.g., surgical instruments, diagnostic equipment), pharmaceuticals (e.g., medicinal products for blood, vaccines), and consumables (e.g., dressings, bandages). Although consumables are coded under the medical devices category in the CPV, they are treated separately in this study due to their specific characteristics and sustainability challenges. Using the CPV classification ensure the analysis to be consistent with European procurement practices, allowing sustainability considerations to be systematically applied to each product group according to its characteristics and procurement requirements.

Each category presents specific sustainability challenges, ranging from complex material composition of medical devices to the high chemical impacts associated to pharmaceuticals. At the same time, opportunities such as the procurement of greener products, reprocessing, and the implementation of take-back schemes represent a way in which circular and green practices can be integrated into healthcare procurement. In subsections 2.4.1, 2.4.2, and 2.4.3, these three product categories are analysed separately highlighting both environmental issues and potential strategies that can mitigate their impact.

2.4.1 Medical devices

Medical devices are defined by the WHO as “instruments, apparatus or machines that are used in the prevention, diagnosis or treatment of illnesses or diseases, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purposes”. Typically, the purpose of a medical device is not achieved by pharmacological, immunological or metabolic means (WHO, 2011).

Environmental challenges are becoming increasingly important for governments and stakeholders, as they could potentially affect the benefits delivered by medical devices (WHO, 2011). Among these challenges, there is the widespread use of single-use devices, which has been further accelerated after the COVID-19 pandemic to comply with strict infection control requirements (Hinrichs-Krapels et al., 2022). The production and disposal of these devices, mainly done in plastic, generate significant hospital waste, which is mainly disposed in landfill, with high environmental impacts due to the slow degradation (McGain et al., 2017). Reducing virgin plastic in devices, however, can be difficult, since recycled plastic often fail to meet quality standards required in the healthcare sector (Lingegård, Martin and Gheitasi, 2025). Besides plastic, other commonly used materials, such as electronics and metals, also have a considerable environmental footprint, as their production requires large amounts of raw materials and energy, leading to GHG emissions and waste, often not correctly segregated and disposed (Noort, Snijder and Weiland, 2025). Therefore, great importance should be given to material selection: sustainable alternatives can help reduce both raw material extraction and waste while maintaining the same clinical outcomes (Montesinos et al., 2024).

Circular strategies, instead, involve modular or recyclable device design, as well as reuse, remanufacturing, recovery or repurposing of devices (Viani, Vaccari and Tudor, 2016). The transition to reusable devices can reduce the emissions compared to single-use devices. Particularly, an LCA study showed that invasive devices show the highest mitigation potential when switched to reusable alternatives (Keil et al., 2023). However, the impact of sterilization, with the considerable amount of energy and water required, may offset part of the benefits. Therefore, more energy efficient sterilization methods should be adopted (De Waele et al., 2024; Montesinos et al., 2024). In addition, manufacturers are increasingly engaging in take-back schemes, such as Siemens, Philips and GE, which have introduced programs to collect high-complexity, high-cost equipment (e.g., X-rays, MRI machines) to refurbish and resell the devices with warranties at a price that is 60-70% lower than the price of a new device (Kane, Bakker and Balkenende, 2018). Medical devices can also be repaired extending their useful life or repurposed at the end-of-life, using discarded products or parts in products with different function (Montesinos et al., 2024). On the other hand, when disposable devices are unavoidable, bio-based or recyclable materials should be used to allow, at least, the recovery of secondary raw materials (Hoveling et al., 2024). However, the suitability of circular strategies mainly depends on the type of device: for high-value, high-criticality devices (e.g. surgical shavers and staplers), reprocessing provides strong cost-benefit potentials but is still a challenge due to the

high criticality of the device and the lack of design for hygienic recovery; high-value, non-critical devices (e.g. imaging equipment), instead, should be redesigned to facilitate remanufacturing, disassembly, or substitution of single components; lastly, low-value, high-criticality devices (e.g. endoscopes) are characterized by high reprocessing and low disposal costs, therefore improvements should be done to the infrastructure, to make reprocessing more appealing (Kane, Bakker and Balkenende, 2018).

Circular opportunities also involve the introduction of new circular business models: equipment renting may ensure updated and well-maintained devices, reprocessing services by original equipment manufacturers (OEM) may reduce safety risks, while sharing platforms may enhance device circulation, enabling hospitals to share, rent or, directly, buy preowned devices, reducing the need for new ones, also limiting capital expenditure (Guzzo et al., 2020). These practices also provide additional benefits, including cost reduction, enhanced organizational reputation, and improved regulatory compliance (Duffy et al., 2023).

2.4.2 Consumables

According to the WHO, consumables are “supply items, sometimes required for the use of medical equipment, that are essential for the performance of diagnostic, therapeutic, monitoring, or hygiene related procedures”. These products, characterized by high-frequency use and short lifecycles, include items such as gloves, masks, protective equipment, and single-use instruments like needles or medical kits. Consumables can be mono-material or multi-material, with polymers and metals being the primary constituents of single-use items, together with glass, textiles, and other composites (Hossain, Ghose and Sahajwalla, 2025).

Their significant environmental impact is mainly due to the large volumes of waste generated and the extensive use of non-biodegradable plastics. LCA studies have shown that the production, transportation, and disposal of single-use consumables contribute substantially to GHG emissions and resource consumption. Also, empirical data from Dutch hospitals indicate that consumables account for a substantial share of the overall environmental impact in healthcare facilities, emphasizing the need for targeted waste reduction and management strategies (Noort, Snijder and Weiland, 2025).

Opportunities to reduce the environmental impact include design improvements, reuse, and replacement of single-use items with reusable alternatives. For instance, disposable custom packs, can be optimized by reducing high-emission materials such as cotton, washing towels

up to 50 times before discarding them, and by removing unnecessary items, reducing the size of custom packs (Campion et al., 2015). In fact, surgical gowns and drapes are already available in the market in washable and reusable forms, making reusable alternatives cost-effective if sterilization infrastructures are present (Noort, Snijder and Weiland, 2025; Torkki et al., 2024b). However, several products, such as bandages or needles, cannot be safely reused, making it essential to recover materials through improved logistic and clear labelling for recycling (Noort, Snijder and Weiland, 2025). This could potentially improve the recycling rate of highly demanded materials like aluminium, with manufacturers that can be also engaged in collecting waste products, which can potentially generate additional material streams, reducing the demand for virgin material (Leissner and Ryan-Fogarty, 2019). Particularly, it has been showed that proper waste management allows to save up to 55% in waste transportation costs for the healthcare organization (Campion et al., 2015).

Procurement plays a key role in driving the transition toward lower-impact consumables and by integrating environmental criteria into procurement decisions. For instance, sustainability is increasingly becoming a mandatory criterion in PPE tenders, supported by the use of LCA metrics and closed-loop systems to evaluate suppliers' environmental performance (Keil et al., 2023).

2.4.3 Pharmaceuticals

Pharmaceuticals, as defined by the European Medicines Agency (EMA), are “substances or combination of substances intended to treat, prevent or diagnose a disease, or to restore, connect or modify physiological functions by exerting a pharmacological, immunological or metabolic action”. While essential for patient care, pharmaceuticals also represent one of the most environmentally impactful product categories in healthcare. In fact, their lifecycle involves resource-intensive production, complex logistic, and problematic end-of-life management, contributing to GHG emissions, biodiversity loss, and hindering the achievement of SDGs (Sánchez et al., 2023).

Manufacturing processes are highly energy demanding and often rely on fossil-based solvents and chemicals, generating significant eco-toxicity when pharmaceuticals are introduced in the environment through human excretion, wash-off of topical products, or improper disposal through toilets and household waste (Gahbauer et al., 2021). Furthermore, the presence of globalized supply chains increases transport-related emissions, while inefficiencies in distribution

and lack of communication can lead to shortages and waste of essential medicines (Boche, Mulugeta and Gudeta, 2022). At the hospital level, expired or unused medicines often end up in landfills or wastewater, representing a source of chemical contamination due to the presence of infectious or radiative substances, which special handling to prevent environmental and human risks (Olawade et al., 2025). In addition, the heavy reliance on single-use packaging, blisters, and vials adds to the volume of non-recyclable waste.

Therefore, reducing the environmental footprint is essential. It can be done through process optimization, renewable energy adoption and green chemistry, which can reduce toxic waste by producing compounds which are equally effective but less toxic and resource intensive. At the same time, circular economy approaches, such as the adoption of recyclable packaging, and use of standardized labelling for disposal, can further support this goal by substantially improving material recovery, avoiding the contamination of water resources and enabling the safe redistribution of unused and unexpired medicines (Olawade et al., 2025; Gahbauer et al., 2021). For instance, blister packs, made from plastic and aluminium, can be redesigned using recyclable materials while maintaining product integrity (Olawade et al., 2025).

Pharmaceutical innovation also plays a key role in sustainability: biosimilars, for example, provide equivalent clinical outcomes but reducing costs and lowering resource use and emissions compared to original drugs. However, their adoption may be slowed by the need of complex and costly infrastructures required for biological production (Roth et al., 2025). In the absence of greener alternatives, hospitals should select the most sustainable drugs should be selected by using tool such as LCA and by evaluating supplier's data about raw material sourcing, production, transportation and packaging (Ong, Birtel and Charbel Issa, 2024).

Hospital pharmacies are increasingly implementing greener practices, such as the collection and safe disposal of unused drugs, improved inventory management to avoid stockpiling, and the prescription to patients trying to avoid leftovers or to reduce GHG emissions choosing, for respiratory treatments, low-carbon inhalers, which alone account for nearly 3% of the healthcare sector's carbon footprint (Leal Filho et al., 2024; Guiu Segura, 2025). Although procurement has a less direct influence on the environmental footprint of pharmaceuticals compared to medical devices and consumables, pharmaceutical procurement strategies that integrate environmental criteria are emerging as a lever for systemic change. These strategies can drive innovation, favour suppliers with demonstrable environmental responsibility, and foster manufacturers' commitment to sustainable practices. This includes promoting recyclable

packaging, encouraging greener logistics, and improving waste management practices (Wen and Liu, 2023; Sánchez et al., 2023).

To provide a systemic overview, Table 2 presents a summary of the main environmental issues and opportunities for each product category.

Table 2 - Environmental issues and opportunities across healthcare product categories

Product category	Environmental issues	Opportunities for sustainability	Role of procurement
Medical devices	• High material and energy consumption • Reliance on single-use plastic • High energy and water consumption during sterilization • Problematic disposal of hazardous components	• Redesign and material substitution • Reprocessing and reuse of single-use devices • Improved waste segregation • Adoption of new circular business models	• Selection of suppliers providing modular, reusable, or recyclable devices • Engagement with OEMs for reprocessing or take-back schemes • Preference for bio-based or recyclable materials
Consumables	• Large volumes of waste • Heavy reliance on plastic and over packaging • High reliance on incineration and landfill as end-of-life management solutions	• Use of biodegradable or recyclable materials • Sustainable sourcing • Reduction of packaging • Improvement in segregation and recycling	• Selection of suppliers offering reusable or lower-impact consumables • Integration of LCA-based evaluation into tenders • Collaboration with suppliers for take-back or closed-loop systems • Preference for products with biodegradable or recyclable materials and optimized packaging
Pharmaceuticals	• Energy-intensive production • Use of hazardous solvents and chemicals • Water contamination through excretion or improper disposal • Global supply chain emissions • Waste from non-recyclable packaging	• Introduction of green chemistry and renewable energy in production • Use of eco-friendly packaging • Implementation of take-back schemes for unused medicines • LCA-based drug selection	• Selection of suppliers with greener manufacturing practices • Promotion of recyclable packaging and greener logistics • Support for waste management and take-back schemes

2.5 Limitations of current procurement models

Current procurement models used in the healthcare sector have traditionally succeeded in ensuring transparency, cost containment, and timely access to essential products. However, when assessed against the growing demand for sustainability, resilience, and innovation, several structural limitations emerge that cut across the different product categories, underscoring the need for rethinking to align them with environmental goals (Hinrichs-Krapels et al., 2022).

A first acknowledged limitation is the excessive reliance on the lowest-price criterion as the primary driver of supplier selection (Salvatore, Boscolo and Tarricone, 2013). An exclusive focus on price often results in trade-offs with quality, safety, and innovation, ultimately hindering the adoption of environmentally preferable solutions. In fact, often price-driven centralized procurement exacerbates inefficiencies and reduces the value delivered to patients by slowing the introduction of technological innovations (Kastanioti et al., 2013). On the other hand, in decentralized procurement, many systems remain fragmented and poorly coordinated, leading to duplications, reduced bargaining power, and limited capacity to implement consistent environmental standards. Particularly, information asymmetry about the performance of the supplier is further increased by a low level of communication between procurers and suppliers, undermining transparency and trust (Boche, Mulugeta and Gudeta, 2022).

A second limitation lies in the insufficient integration of sustainability and innovation tools in procurement decisions. Although green public procurement is increasingly recognized as a strategic lever, its actual implementation in healthcare remains at an early stage. Tools such as LCA and HTA are rarely embedded in decisions-making, leading to choices primarily driven by price, while overlooking long-term environmental impacts (Kastanioti et al., 2013). The high purchasing power of healthcare organizations, particularly in centralized procurement models, could instead be used to stimulate the production, supply and diffusion of green products (Etse, McMurray and Muenjohn, 2021). Moreover, the introduction of planning and control systems, combined with HTA, could help in the requirements specification phase of complex medical devices, which are mainly procured through negotiations with supplier and whose return on investment is visible only over the long term (Callea et al., 2017; Salvatore, Boscolo and Tarricone, 2013).

Another limitation is represented by regulatory and bureaucratic constraints, which further inhibit the adoption of innovative practices due to formal requirements, designed to safeguard

transparency and competition, but that can inadvertently reduce flexibility and slow down the integration of sustainability criteria. In centralized procurement models, policies dedicated to specific healthcare product categories and the creation of teams that also involve staff from different organizations are pivotal in ensuring the satisfaction of organization's requirements and achievement of sustainability goals (Vogler, Bauer and Habimana, 2022).

A further barrier lies in the capabilities of procurement professionals. In many contexts, procurement is still perceived as an administrative rather than strategic function, resulting in insufficient expertise to address sustainability, digital innovation, and risk management to foster the implementation of innovative and environmental considerations in procurement processes. (Stek and Belotti, 2025). Furthermore, the lack of advanced analytical and digital skills limits the ability to exploit big data in evaluation and monitoring, limiting the optimization of resource sourcing, reduction of waste and inventory management (Ahsan et al., 2022).

Lastly, procurement processes face significant vulnerabilities in supply chain resilience. Excessive reliance on centralized procurement models exposes healthcare systems to shortages, dependency, and geopolitical risks, as highlighted by recent disruptions in pharmaceuticals and vaccines (Nakambale and Bangalee, 2021; Gianfredi et al., 2021). In fact, centralized models suffer from rigidity and overdependence on single suppliers, limiting responsiveness to local needs and shortages as tenders typically select only one supplier. This situation forces procurers to quickly seek alternatives paying higher prices, incurring transaction costs, and compromising environmental objectives (Anthony et al., 2025; Vogler, Bauer and Habimana, 2022).

2.6 Research gaps

The reviewed literature reveals significant gaps that prevent current procurement models from fully aligning with environmental goals, undermining the understanding of how procurement processes could operationalize green and circular procurement practices across all procurement stages, including needs identification, specification development, supplier selection, contracting, and evaluation and performance monitoring. Additionally, even though instruments like LCA, HTA, or ESG-based frameworks are recognized as valuable, they remain marginal in procurement decisions-making, leading to an absence of harmonized criteria that limits the comparability of environmental performance and reduces the ability of procurers to make evidence-based, sustainability-oriented choices (Hinrichs-Krapels et al., 2022). Specifically, there is a lack of clear frameworks, criteria, and operational approaches that healthcare organizations

can adopt to systematically integrate environmental objectives into procurement models. This includes guidance on how to translate sustainability priorities into procurement decisions or how to align procurement strategies with broader organizational sustainability goals.

Moreover, literature tends to privilege a system wide approach, giving limited attention to specific product categories. Procurement models are analysed generically, without differentiating between product categories, each of which presents specific challenges in terms of lifecycle impacts, waste management, and environmental footprint (Hoveling et al., 2024; D'Alessandro et al., 2024). This creates a gap in understanding the extent to which challenges and opportunities differ across medical devices, consumables and pharmaceuticals, and what category-specific guidelines are needed to redesign procurement models to simultaneously ensure cost efficiency, respect of quality standards and alignment with sustainability objectives. Therefore, to address these research gaps, this study aims to answer to the Research question outlined in Section 2.7.

2.7 Research question

Based on the limitation of current procurement models and on the gaps highlighted in Section 2.6, this thesis addresses the redesign of healthcare procurement models to align them with environmental sustainability goals. In fact, current models do not sufficiently incorporate green and circular practices across different product categories, creating both conceptual and practical challenges for policymakers, procurement managers, and suppliers. In this context, the research question guiding this thesis is: *How can current healthcare procurement models be redesigned to align with environmental and circular sustainability goals across different healthcare product categories, such as medical devices, consumables, and pharmaceuticals?*

To answer this question, the thesis firstly maps the challenges and opportunities associated with green and circular procurement of medical devices, consumables, and pharmaceuticals. Secondly, the limitations of current procurement models in embedding sustainability principles are identified with the ultimate aim of developing guidelines for adapting and redesigning procurement models to incorporate sustainable and circular practices in a category-specific manner. By addressing these objectives, the thesis will contribute to a deeper understanding of how sustainability can be operationalized in healthcare procurement, while also offering practical insights for decision-makers and policymakers.

3. Methodology

This chapter outlines the methodological approach adopted to address the research question and objectives introduced in Chapter 2.

3.1 Choice of the Delphi Model

Given the exploratory nature of the study and the need to capture expert knowledge on how current healthcare procurement models could be redesigned to align with environmental sustainability goals, the Delphi technique was considered the most appropriate. More specifically, this study adopts a ranking-type Delphi, which is particularly suited for the identification, selection and prioritisation of issues through iterative rounds of expert evaluation, as discussed by Paré et al. (2013). This variant is especially appropriate when the objective is to structure expert judgement around the relative importance of a set of items rather than to forecast future scenarios. In Subsections 3.1.1 and 3.1.2, the key characteristics of the Delphi approach and a discussion on the rationale for its application in the study of healthcare procurement sustainability are presented.

3.1.1 Key characteristics of the Delphi technique

The Delphi technique is a structured research methodology originally developed in the 1950s by the RAND Corporation to forecast technological developments and future scenarios, with the aim of obtaining the most reliable consensus from a group of experts. However, over time, the technique has significantly evolved, becoming widely adopted in multiple disciplines, including public policy and planning, healthcare research, and management studies (Linstone, Turoff and Helmer, 2002). It is defined as a multi-stage survey process designed to achieve consensus among experts on specific issues, providing a series of questionnaires with controlled feedback in successive rounds (Keeney, Hasson and McKenna, 2010). In particular, the Delphi method proved to be most valuable when accurate data are unavailable or costly to obtain, or when the complexity of the issue requires specialized insight of experts (Linstone, Turoff and Helmer, 2002).

The Delphi technique is characterized by several key features:

- Iterative process. The method unfolds through multiple rounds of questionnaires. In each round, participants provide their judgements, which are then aggregated and

returned to the group in a structured manner. This iterative structure provides experts with the opportunity to reconsider, at least once, their opinions in light of the group's input, progressively refining the results (Linstone, Turoff and Helmer, 2002). Typically, the number of rounds is between two and four, depending on time constraints and whether the study begins with broad or detailed questions (Keeney, Hasson and McKenna, 2001).

- Expert participation. The method involves experts with deep knowledge of the issue under study. Generally, a panel size between 20 and 30 experts is acceptable, although it depends on group dynamics, the purpose of the project and the time frame for data collection (Keeney, Hasson and McKenna, 2001; Kembro et al., 2017). Only qualified experts are involved relying on a careful selection process, in order to obtain informed insights into the research problem and, typically, a heterogeneous sample is preferred to ensure the collection and mapping of different opinions (Keeney, Hasson and McKenna, 2001).
- Anonymity of participants. Unlike traditional group discussions, the Delphi method maintains the anonymity of participants to prevent the influence of dominant individuals and minimize social or hierarchical pressures, thereby fostering more balanced and independent judgments. However, there is never complete anonymity: experts are known by researchers, and participants may know each other even if no one is able to attribute responses to any other member in the group (Keeney, Hasson and McKenna, 2010).
- Controlled feedback. Instead of unstructured debate, participants receive a synthesized summary of the group's responses, often including statistical indicators such as median or interquartile ranges (IQR), which are valuable metrics for assessing consensus when Likert scale responses are used. This encourages reflection and potential revision of individual views, without direct confrontation (Keeney, Hasson and McKenna, 2010).
- Statistical group response. Measures such as medians, IQR, and, in some cases, coefficient of concordance (e.g. Kendall's W) provide an objective basis for evaluating the level of convergence or divergence across rounds. This statistical representation of the group judgement is essential to determine whether consensus has been reached and to monitor the stability of responses over successive iterations (von der Gracht, 2012).

- **Consensus orientation.** The Delphi technique typically aims to achieve consensus, or at least to narrow down divergences among experts. Importantly, consensus in Delphi does not necessarily mean unanimity or that the correct answer has been found, but rather identifies areas of agreement or persistent disagreement, both of which can provide valuable insights (Keeney, Hasson and McKenna, 2001). However, not all Delphi studies seek consensus: some versions, such as the Policy Delphi, are intended to support decision-making by comparing different perspectives on a topic (Keeney, Hasson and McKenna, 2010).
- **Flexibility.** Delphi can be designed for exploratory purposes, such as generating new ideas in under-researched areas, or for confirmatory purposes, such as validating frameworks or identifying priorities. It has been applied in both qualitative and quantitative studies across multiple fields, including healthcare (Keeney, Hasson and McKenna, 2010).

3.1.2 Rationale of using Delphi model in the healthcare sustainability context

By enabling iterative rounds of reflection, feedback, and controlled interaction, the Delphi technique provides a reliable way to build consensus and identify shared priorities, even in highly complex domains such as sustainability in healthcare procurement, where established evidence and clear guidelines are limited or lacking (Sudusinghe and Seuring, 2025; Sauer and Seuring, 2019). The Delphi technique is particularly well suited to address these challenges, as it is designed for situations in which knowledge is incomplete and where expert consensus is required to inform decision-making. In particular, its iterative and anonymous structure enables participants to reflect on their judgements, reconsider their views in light of group feedback and progressively converge towards shared positions (Keeney, Hasson and McKenna, 2010).

Recent applications further demonstrate the suitability of the Delphi method for addressing the sustainability related challenges within the healthcare sector. For instance, Kanokphanvanich, Rattanawong and Vongmanee (2023) apply a Delphi based approach to identify healthcare workers' perspectives on sustainable healthcare supply chain, highlighting its effectiveness in capturing multidimensional sustainability considerations while prioritising patient safety.

In light of these considerations, the adoption of Delphi in this study is particularly relevant, enabling the integration of literature findings with expert knowledge and supporting the

construction of a structured consensus on the facilitating and inhibiting factors for green and circular procurement, as well as on the limitations of current procurement models. Moreover, this approach contributes to the understanding of how procurement models could be redesigned to align with environmental sustainability goals, while tailoring the discussion to the specific product categories considered, namely medical devices, consumables, and pharmaceuticals, ensuring that the results are both context-sensitive and applicable across the healthcare sector.

3.1.3 Methodological validity

Validity refers to the ability of a research method to accurately measure the attributes of the construct under study (Keeney, Hasson and McKenna, 2010). In Delphi studies, several dimensions of validity are commonly discussed, including internal validity, external validity, and construct validity. Internal validity refers to the extent to which the results accurately reflect experts' opinions and are not affected by methodological bias; external validity concerns the generalizability of the findings to other contexts or population of experts; and construct validity addresses whether the study adequately captures the theoretical concepts under investigation. In this respect, the pre-testing of the questionnaire contributes to strengthening construct validity by ensuring clarity, relevance, and proper operationalisation of the key concepts explored in the study. The Delphi model has been shown to support validity as judgements are provided by a group of experts, rather than a single individual, and also because of the use of multiple rounds that combine both open-ended and closed-ended questions, allowing participants to revise their views in light of controlled feedback (Keeney, Hasson and McKenna, 2010).

3.2 Study design

The design of the study consists of three main components: the selection of the expert panel, the development of the questionnaires for each Delphi round, and the definition of the specific objectives associated with each round (Paré et al., 2013). In practice, the study followed seven key steps: (1) expert selection, (2) development of Round 1 questionnaire, (3) Round 1 online interviews, (4) thematic coding and analysis of Round 1 responses, (5) development of Round 2 questionnaire, (6) Round 2 administration and data collection, and (7) quantitative and statistical analysis of Round 2 responses. Subsections 3.2.1, 3.2.2 and 3.2.3 describe each of these elements, outlining the methodological choices and practical considerations that guided the study design. To provide a visual overview of the Delphi process, a flowchart illustrating the main steps of the study is presented in Figure 6.

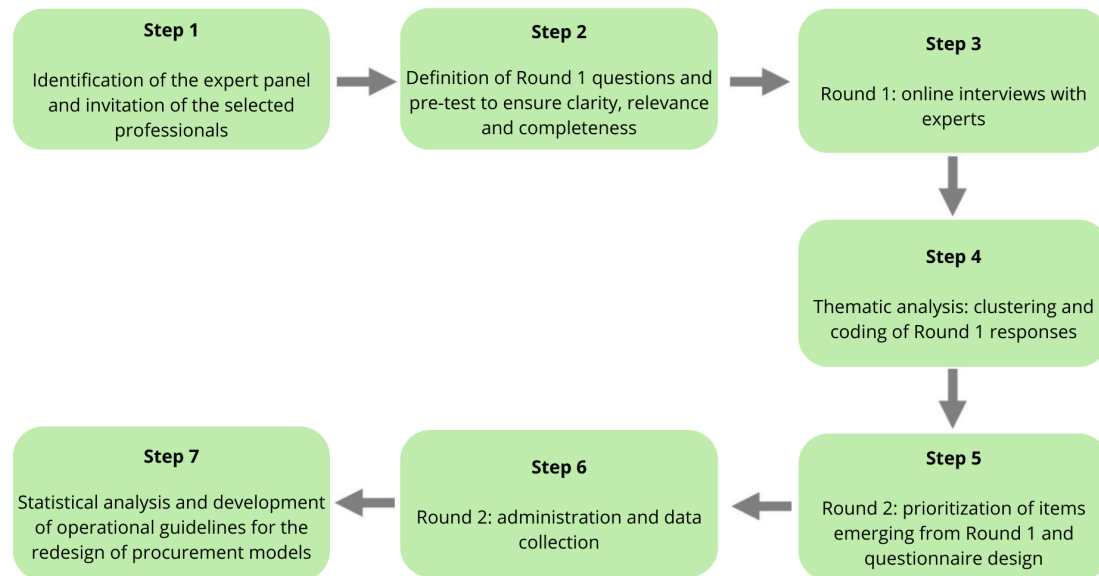


Figure 6 - Steps of the Delphi study

3.2.1 Expert panel selection

The robustness of a Delphi study strongly depends on the careful selection of the experts, as the quality and diversity of participants directly affect the validity and credibility of the results (Peron et al., 2025). In line with established methodological guidance, the expert panel for this study was designed to ensure a heterogeneous representation of knowledge domains and professional backgrounds relevant to healthcare procurement sustainability, allowing the collection of a broad spectrum of opinions (Keeney, Hasson and McKenna, 2001; Giunipero, Hooker and Denslow, 2012).

An expert can be defined as an individual with substantial knowledge and experience related to the subject under investigation. In fact, unlike traditional surveys, experts do not represent a random sample of a population but are intentionally selected based on their ability to provide in-depth and informed judgements, thereby positively affecting the quality of the study outcomes (Schulze and Bals, 2020). Additionally, to ensure commitment throughout the multiple rounds of the Delphi process, experts should have a strong interest in the topic and feel involved. Therefore, it is important to find a balance in the selection process by choosing relatively impartial participants, ensuring that their contributions reflect their competencies without being affected by desirability bias (Keeney, Hasson and McKenna, 2010).

Based on these considerations, professionals with different roles were targeted, including procurement managers and hospital pharmacists with proven experience in healthcare

procurement, in order to reflect the scope of the research question and adequately address the specificities of each product category. Moreover, diversity should also be sought in terms of geographical and institutional background to capture perspectives from different healthcare contexts. In this study, participants are based in multiple Italian regions, namely Piedmont, Liguria, Aosta Valley, Veneto, and Lombardy, and work within institutions operating at hospital level (Azienda Ospedaliero-Universitaria, AOU), local healthcare agency level (Azienda Sanitaria Locale, ASL) or regional healthcare institution level, thus ensuring a variety of perspectives and opinions.

Although there is no universal consensus on the ideal number of participants in a Delphi study, methodological literature suggests that panels comprising between 20 and 30 experts provide a good compromise between diversity of perspectives and feasibility of data collection and analysis, without leading to data management problems (Okoli and Pawlowski, 2004; Kembro et al., 2017). In line with these recommendations, a total of 26 experts were invited to participate in this study. Of these, 25 responded to Round 1, and 20 of them completed Round 2.

Recruitment was carried out through targeted invitations to recognized experts in the field, leveraging academic networks and institutional contacts. In accordance with Delphi guidelines, anonymity was guaranteed to all participants in order to minimize peer influence and potential bias, thereby encouraging independent contributions (Keeney, Hasson and McKenna, 2010). Personal information was collected, in the first section of the Round 1 questionnaire, solely to illustrate the composition of the panel in terms of professional roles, institutional affiliation and years of experience in healthcare procurement. Table 3 presents an overview of the expert panel composition, assigning an identification code to each respondent based on their employing organization and summarizing their main characteristics, including role, years of experience, and healthcare product responsibility. In addition, Figure 7- Figure 10 provide graphical representations of the expert panel composition, illustrating the distribution of respondents according to institution type, professional role, and year of experience. These visualizations facilitate a rapid overview of the panel characteristics and highlight the diversity of perspectives included in the study. Overall, the panel includes experts from different types of healthcare organisations and professional backgrounds, with a predominance of procurement-related roles and a generally high level of professional experience. This diversity supports the reliability of the Delphi results by incorporating multiple perspectives on healthcare procurement

Table 3 - Expert panel characteristics and healthcare product responsibilities

Expert ID	Professional Role	Organization type	Years of experience in the healthcare sector	Years of experience in the current organization	Expert's product responsibility			Round 1	Round 2
					Medical devices	Consumables	Pharmaceuticals		
A1	Head of the Operational Management Unit	Local Healthcare Agency	24	1	✓	✓	✓	✓	
B1	Head of Hospital Pharmacy	Local Healthcare Agency	25	16	✓		✓	✓	✓
B2	Head of Centralized Healthcare Warehouse	Local Healthcare Agency	17	16	✓		✓	✓	✓
C1	Head of Hospital Pharmacy	Local Healthcare Agency	20	9	✓		✓	✓	✓
C2	Head of the Logistic and IT Services Unit	Local Healthcare Agency	30	2	✓	✓	✓	✓	✓
D1	Head of Hospital Pharmacy	Local Healthcare Agency	17	13	✓		✓	✓	✓
E1	Head of the Complex Operational Unit for Logistic	Regional institution for healthcare planning	25	4	✓		✓	✓	
F1	Head of Hospital Pharmacy	Local Healthcare Agency	25	17	✓		✓	✓	✓
G1	Head of Hospital Pharmacy	Hospital	31	16	✓		✓	✓	✓
G2	Senior Hospital Pharmacist	Hospital	18	6	✓		✓	✓	✓
G3	Senior Hospital Pharmacist	Hospital	27	25	✓		✓	✓	

Table 3 (Continue)

					Expert's product responsibility				
Expert ID	Professional Role	Organization type	Years of experience in the healthcare sector	Years of experience in the current organization	Medical devices	Consumables	Pharmaceuticals	Round 1	Round 2
H1	Deputy Director of the Hospital Pharmacy Unit	Local Healthcare Agency	31	1	✓		✓	✓	✓
H2	Head of the Procurement and Supply Office	Local Healthcare Agency	28	18	✓	✓		✓	✓
I1	General Director	Regional institution for healthcare planning	15	2	✓	✓	✓	✓	✓
J1	Administrative Manager	University Hospital	25	16	✓	✓	✓	✓	✓
J2	Head of Hospital Pharmacy	University Hospital	40	39	✓		✓	✓	✓
K1	Head of the Procurement and Supply Office	Local Healthcare Agency	18	18	✓	✓	✓	✓	✓
K2	Head of the Pharmaceutical Unit	Local Healthcare Agency	30	9	✓		✓	✓	
L1	Head of Hospital Pharmacy	University Hospital	25	13	✓	✓	✓	✓	
L2	Senior Hospital Pharmacist	University Hospital	12	12	✓	✓		✓	✓
M1	Head of Procurement and Logistic	Local Healthcare Agency	27	2	✓	✓	✓	✓	✓

Table 3 (Continue)

Expert ID	Professional Role	Organization type	Years of experience in the healthcare sector	Years of experience in the current organization	Expert's product responsibility			Round 1	Round 2
					Medical devices	Consumables	Pharmaceuticals		
M2	Head of Hospital Pharmacy	Local Healthcare Agency	27	24	✓		✓	✓	✓
N1	Head of Hospital Pharmacy	Local Healthcare Agency	35	35			✓	✓	✓
N2	Head of the Unit for Pharmaceutical Continuity between Hospital and Community Care	Local Healthcare Agency	16	16			✓	✓	✓
O1	Researcher	Regional Research Institution	15	13	✓		✓	✓	✓
Totals¹			24.1	13.7	23	9	23	25	20

¹ In the “Totals” row, the values reported for “Years of experience in the healthcare sector” and “Years of experience in the current organization” represents the average years of experience across all respondents. Conversely, the values in the healthcare product category, Round 1 and Round 2 columns indicate the number of respondents associated with each product category or who participated in each round.

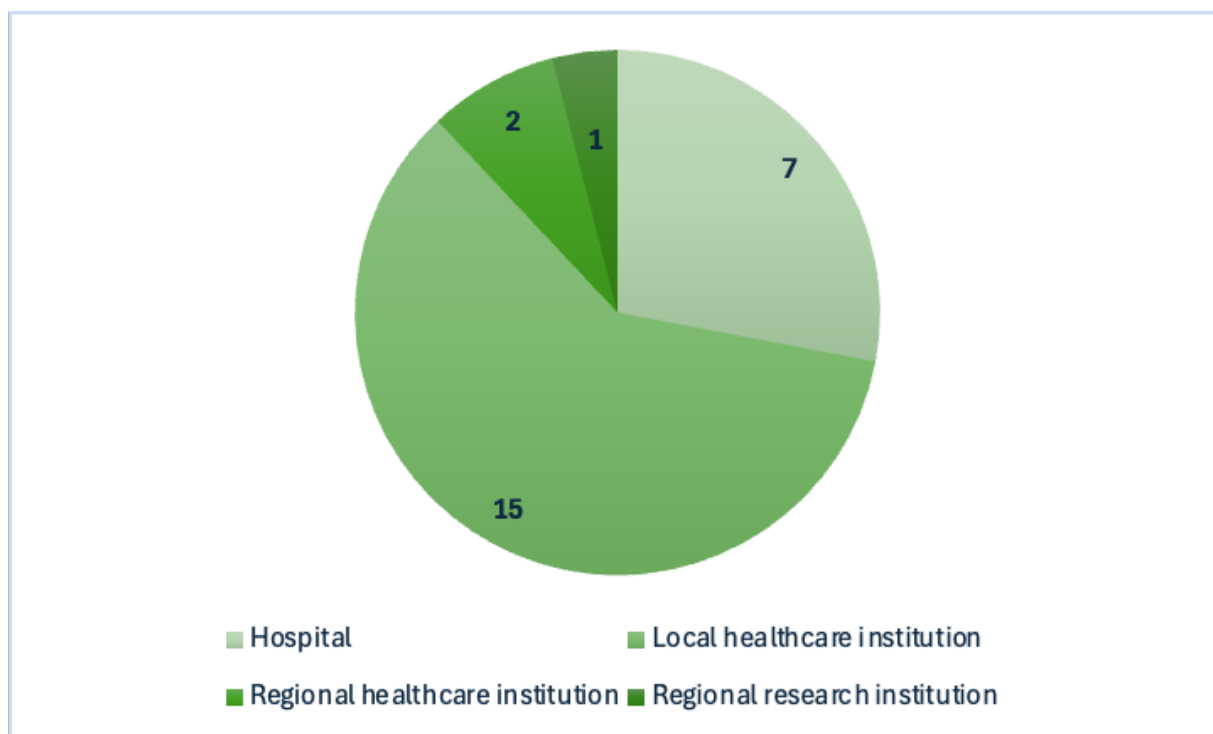


Figure 7 - Expert distribution by type of institution

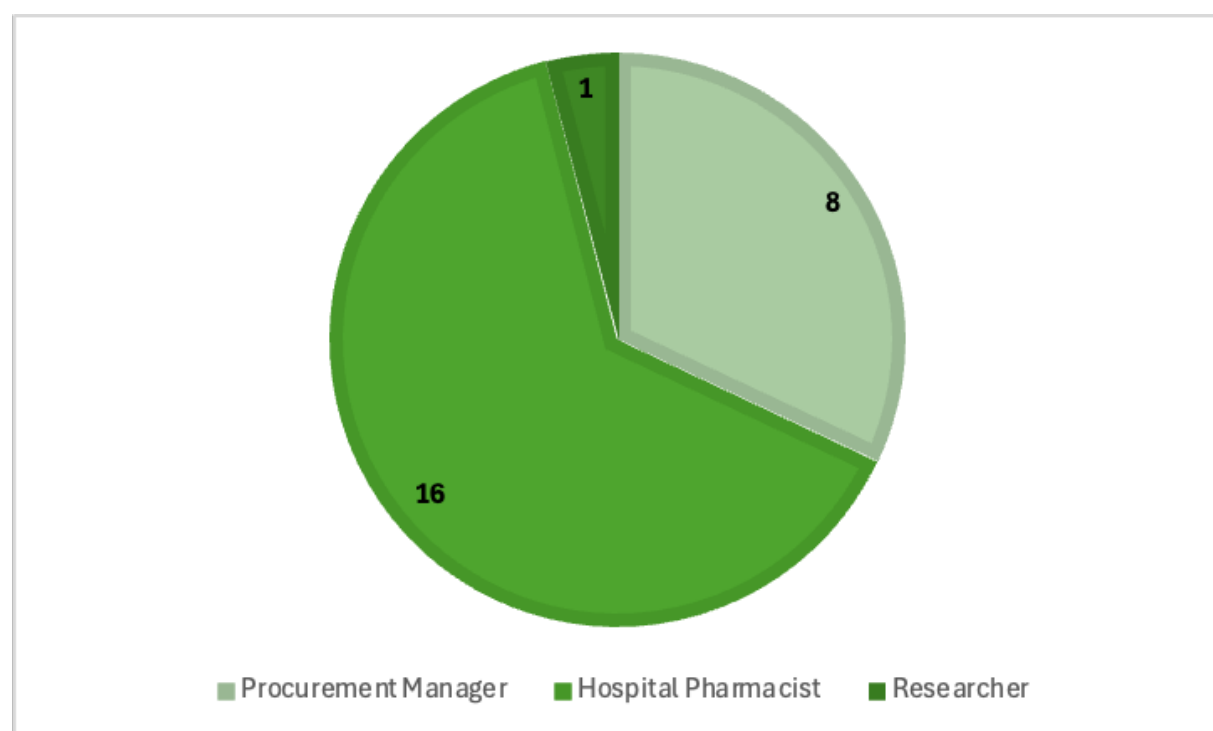


Figure 8 - Expert distribution by professional role

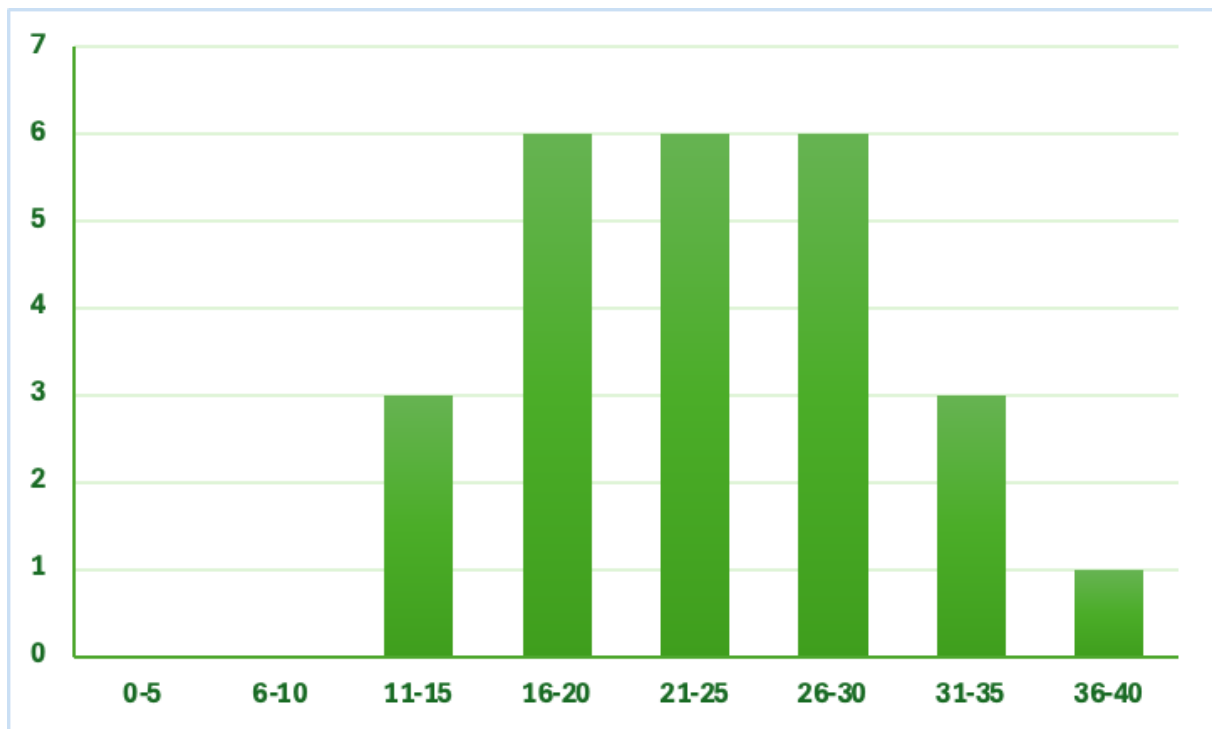


Figure 9 - Expert distribution by years of experience in the healthcare sector

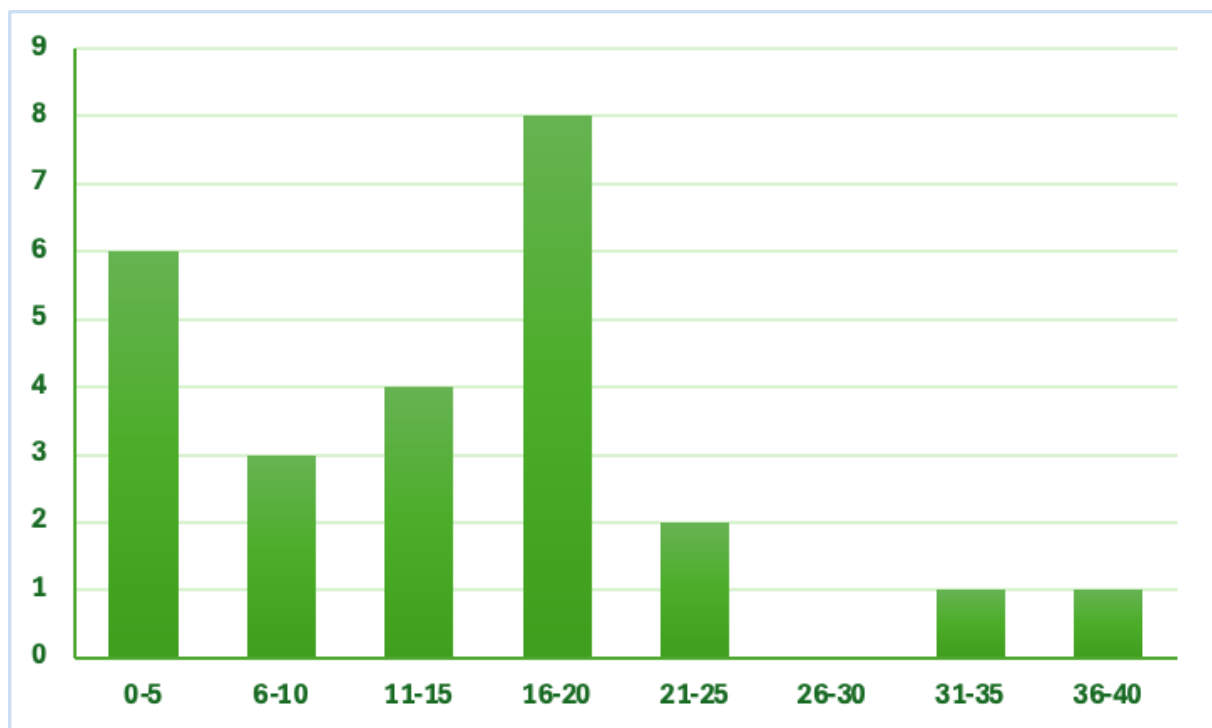


Figure 10 - Expert distribution by years of experience in the current organization

3.2.2 Objectives of each round

The iterative design of Delphi is intended to combine the advantages of diverse experts viewpoints with a structured process of feedback and refinement, ensuring that the outcomes generated are both comprehensive and systematically validated by the expert panel (Okoli and Pawlowski, 2004; Linstone, Turoff and Helmer, 2002; Keeney, Hasson and McKenna, 2001).

Round 1 has an exploratory function. Experts are invited to identify and discuss the main motivations for introducing environmental sustainability into healthcare procurement, existing green and circular procurement practices and their associated barriers, critical weaknesses of current procurement models, and preliminary recommendations for their redesign. According to Delphi methodological literature, this exploratory phase has the aim to capture a broad spectrum of expert knowledge and to ensure that the subsequent round is grounded in practitioners' perspectives rather than predefined assumptions (Okoli and Pawlowski, 2004; Nasa, Jain and Juneja, 2021).

Building on the results of Round 1, Round 2 aims at consolidating and prioritising the identified items, asking experts to assess the relevance of the proposed items, contextually identifying areas of convergence among the experts and strengthening shared priorities across the panel. This step reflects the core purpose of the Delphi technique, which is to iteratively structure expert input through controlled feedback in order to inform decision-making in contexts characterised by complexity and limited empirical evidence (Linstone, Turoff and Helmer, 2002; Keeney, Hasson and McKenna, 2001).

3.2.3 Questionnaires development

The questionnaires were developed following a structured and iterative design consistent with the principles of the Delphi technique and tailored to the specific objectives and scope of this study. Established methodological guidelines for Delphi studies were followed, with particular attention to clarity, progressive refinement of questions across rounds, and the avoidance of ambiguity and excessive questionnaire length. Two Delphi rounds were structured to identify the main themes, determine the most relevant items, and seek expert consensus, while maintaining a high response rate. According to prior Delphi literature, the number of rounds was defined a priori and considered sufficient to achieve the study objectives, while also avoiding a decline in response rate (Okoli and Pawlowski, 2004; Giunipero, Hooker and Denslow, 2012;

Keeney, Hasson and McKenna, 2010). Each questionnaire was characterised by a distinct design and mode of administration (Subsections 3.2.3.1 and 3.2.3.2). The content and structure of the Round 2 questionnaire were directly informed by the analysis of responses collected during the first round, ensuring methodological continuity and coherence across rounds.

3.2.3.1 Round 1 questionnaire development

Based on the analysis of the literature and the identified research question, Round 1 was structured with both closed and open-ended questions to allow experts to freely share their views and experiences regarding sustainable and circular procurement in healthcare. This format was chosen to maximize the diversity of inputs and reduce potential researcher bias in framing possible answers (Schorderet et al., 2023; Keeney, Hasson and McKenna, 2010). For the closed-ended questions, experts could choose multiple options; for the open-ended questions, they were asked to share their ideas and indicate the applicable product category.

The questionnaire was divided into two sections: the first section focused on the respondent demographics, to contextualize the answers, while the second section focused on current healthcare procurement models, their limitations, the motivations to integrate environmental sustainability into healthcare procurement, practices and barriers related to green and circular procurement and suggestions about elements to redesign to make healthcare procurement more sustainable. Moreover, to capture differences, experts were invited to provide differentiated responses across product categories, namely medical devices, consumables and pharmaceuticals, while also being allowed to add clarifications or additional considerations where relevant. The only closed question in Round 1 asked experts to identify the healthcare procurement models employed in their organisations, choosing among autonomous procurement by individual local healthcare agencies, regional collaborative procurement involving multiple local healthcare agencies, centralised procurement through national or regional purchasing centres, and direct procurement without tender. The content of the questionnaire was grounded in the literature on sustainable healthcare procurement to ensure relevance and conceptual consistency (Keeney, Hasson and McKenna, 2001).

Round 1 questionnaire was administered through one-to-one online interviews with experts. Although the Delphi technique is commonly implemented through asynchronous questionnaire, the use of semi-structured interviews in the first round was intended to minimise potential misunderstandings in the interpretation of questions and to ensure a shared understanding of key concepts related to sustainable healthcare procurement. Each interview lasted on average

approximately 45 minutes. This approach allowed the interviewer to clarify questions where necessary while preserving the exploratory nature of the Delphi process. Moreover, the use of open-ended questions in the initial round enables a broad exploration of expert knowledge without constraining responses to predefined assumptions (Keeney, Hasson and McKenna, 2010; Schorderet et al., 2023; Leao et al., 2025).

Prior to this, a pre-test of the Round 1 questionnaire was conducted with three academics, with expertise in supply chain management, sustainability, and circular economy, and one practitioner, an experienced healthcare procurement manager, to verify clarity, length, and usability, minimizing the risk of misinterpretation, and respondent fatigue.

The Round 1 interviews were conducted over a period of approximately one and a half months, from mid-October 2025 to the end of November 2025. This timeframe allowed sufficient flexibility to accommodate experts' availability while ensuring consistency in data collection. The complete Round 1 questionnaire, along with a glossary of the term used, is provided in Appendix 1.

3.2.3.2 Round 2 questionnaire development

Based on the qualitative analysis and thematic synthesis of Round 1 responses, the Round 2 questionnaire was developed by translating the emergent themes into a set of closed-ended statements. In the phase, identical answers were removed, while overlapping responses were consolidated and compared with literature findings to reformulate key items to be carried forward to Round 2. This transformation from qualitative to quantitative data is a well-established practice in Delphi research, enabling the validation of the list of items derived from the Round 1, and the identification of areas of convergence or divergence among experts (Okoli and Pawlowski, 2004; Sudusinghe and Seuring, 2025).

To ensure that the Round 2 questionnaire focused on themes that were both recurrent and shared across organizational contexts, explicit selection criteria were applied when translating Round 1 findings into closed-ended items. Specifically, only statements mentioned by at least four individual experts, or by at least three experts working for three different organisations, were retained for inclusion in the second round. This approach allowed the questionnaire to reflect not only the frequency of individual responses, but also the diversity of organisational perspectives represented within the expert panel.

The selected statements were evaluated by the experts using Likert-type scales, allowing for the systematic assessment of perceived relevance, and level of agreement (Okoli and Pawlowski, 2004). Likert-type scales are widely adopted in Delphi study to facilitate consensus measurement while preserving the ordinal nature of expert judgements (Koo and Yang, 2025; Lange et al., 2020). In this study, 5-points Likert scales were used, ranging from 1 (“very unimportant”) to 5 (“very important”) (Li et al., 2024). In addition to the quantitative ratings, respondents were given the opportunity to provide optional qualitative comments to further explain or contextualise their evaluations.

The structure of the Round 2 questionnaire reflected both the findings of the first round and the characteristics of the product categories under investigation. Practices and barriers to green and circular procurement were assessed separately for pharmaceuticals and for a combined category of medical devices and consumables. This merging was motivated by two considerations: consumables were consistently described by experts as representing a relatively marginal share of healthcare procurement expenditure compared to medical devices and pharmaceuticals; also, within the CPV, medical devices and consumables are classified under the same category named “medical equipment”. This consolidation allowed for a more focused and meaningful evaluation while maintaining consistency with existing procurement classifications and decreasing respondents fatigue due to the high number of items.

With respect to motivational factors driving the integration of environmental sustainability into healthcare procurement, experts were asked to provide a single evaluation applicable across categories, as the motivations emerged from Round 1 were generally perceived as transversal rather than category specific. Conversely, for elements subject to potential redesign, statements were separately evaluated for each healthcare procurement model identified and validated in Round 1, allowing for a differentiated assessment of redesign opportunities across alternative procurement approaches. The complete Round 2 questionnaire, along with the presentation email sent to experts, is provided in Appendix 2 – Round 2 material.

The Round 2 questionnaire was administered asynchronously through an online survey tool (Jotform). It was distributed to experts in mid-December 2025, with an initial response deadline of two weeks. To maximise participation and reduce non-response bias, an additional two-week extension was granted, resulting in the conclusion of the second round in mid-January 2026. This asynchronous approach is consistent with standard Delphi implementations and allowed experts to reflect on their responses independently (Keeney, Hasson and McKenna, 2010).

3.3 Data analysis

There is no standard approach to analysing data from Delphi rounds, as it largely depends on factors such as the type of questions, the number of respondents, and the purpose of the study (Keeney, Hasson and McKenna, 2010). In this study, data collected through the Delphi technique are analysed using a combination of qualitative and quantitative methods. After the first round, qualitative responses are examined through coding and thematic analysis to identify recurring answers and key themes, in order to prepare for the subsequent round (Subsection 3.3.1). In addition, descriptive quantitative analysis is conducted at the end of Round 1 to summarise experts' responses and support the prioritisation of items to be carried forward into Round 2. Quantitative measures are then applied to assess both the relevance of the items and the level of consensus among experts after Round 2 (Subsection 3.3.2). Finally, considerations regarding validity and methodological limitations are addressed to ensure the rigor and robustness of the study findings (Subsection 3.3.3).

3.3.1 Coding and thematic synthesis

The qualitative data collected during Round 1 were analysed through a structured process of coding and thematic synthesis. This step was essential to transform open-ended expert responses into organised information that could be systematically evaluated in the subsequent Delphi round (Keeney, Hasson and McKenna, 2010).

The coding process primarily followed an inductive approach, allowing themes to emerge directly from experts' responses and preserving the exploratory nature of the first Delphi round as well as the richness of diverse viewpoints (Schulze and Bals, 2020; Keeney, Hasson and McKenna, 2010). At the same time, a limited deductive orientation was maintained by using the research objectives and relevant literature to guide the interpretation and organisation of the emerging themes, ensuring alignment with the study focus (Leao et al., 2025).

All interview transcripts from Round 1 were first reviewed in their entirety to gain familiarity with the data and an overall understanding of the breadth of expert inputs. An initial open coding process was then conducted, during which meaningful segments of text were assigned descriptive codes reflecting the content of the responses. Identical answers were first removed, while similar statements were grouped under a single code. Synonyms and overlapping concepts were identified and merged, ensuring consistency in terminology and clarity in the formulation of emerging themes (Sudusinghe and Seuring, 2025; Okoli and Pawlowski, 2004). Particular

attention was paid to wording, since the resulting statements were intended to be presented to experts in Round 2 (Keeney, Hasson and McKenna, 2010).

Following the initial coding, three structured data files, one for each product category, were created to systematically organise the responses according to thematic areas, including motivations, practices, barriers, obstacles to sustainable healthcare procurement, limits of current procurement models, and redesign elements. For each statement, a keyword and a brief description were assigned. Then, codes were iteratively reviewed, refined, and grouped into higher-order categories through a process of thematic synthesis and keyword analysis. Overlapping or conceptually similar codes were merged, while distinct themes were retained to reflect the diversity of expert viewpoints. This iterative process was conducted independently by three researchers and continued until consensus was reached, ensuring the robustness and reliability of thematic classification and resulting in the identification of coherent thematic clusters. In addition, the analysis focused not only on the identification of recurring themes, but also on their distribution across different organisational contexts. In particular, the respondents who mentioned each statement, as well as the procurement models they referred to, were also recorded.

To select the items to be included in Round 2, an explicit cut-off criterion was applied. This step corresponds to the narrowing-down phase of a ranking-type Delphi, which is a critical stage requiring transparent and clearly specified item selection rules to ensure methodological rigour. Accordingly, only statements mentioned by at least four individual experts or by at least three experts belonging to three different organizations were retained. This criterion allowed for a balance between capturing a wide range of perspectives and avoiding excessive information loss (Paré et al., 2013). This process resulted in a coherent set of themes that could be meaningfully assessed and prioritized in the subsequent round (Xu, 2020; Sauer and Seuring, 2019).

3.3.2 Criteria for consensus

Establishing clear and transparent criteria for measuring consensus is a crucial step in Delphi studies, particularly in ranking-type applications, as it ensures methodological rigour and comparability of findings across different rounds (Paré et al., 2013). In this study, expert consensus was assessed using four complementary indicators widely adopted in Delphi research: the mean, the median, the interquartile range (IQR), and the Kendall's W coefficient of concordance. While the mean, the median and the IQR assess relevance and consensus at the item level,

Kendal's W coefficient of concordance was used to evaluate the overall degree of agreement among experts across all statements. Together, these measures provide a robust evaluation of agreement, capturing both the central tendency of expert ratings and the degree of concordance across the panel (Diamond et al., 2014; von der Gracht, 2012). Also, these indicators have proved particularly suitable when ordinal scales, such as a 5-point Likert scale, are employed (Keeney, Hasson and McKenna, 2010).

The mean represents the arithmetic average of all expert ratings assigned to a given item and provides a synthetic measure of the overall perceived relevance. Although the use of the mean with ordinal data is debated, it remains widely applied in Delphi studies to facilitate interpretability, comparability across items, and subsequent statistical analyses (Diamond et al., 2014; von der Gracht, 2012). Therefore, the mean was calculated for each statement and used as a complementary indicator of relevance alongside the median.

The median represents the central value of an ordered set of data, dividing the distribution into two halves. After sorting data in ascending order, the median can be determined: if the number of values is odd, the median corresponds to the central value; if the number of values is even, the median is the arithmetic mean of the two central values. Unlike the mean, the median is not influenced by outliers or skewed distributions, making it particularly appropriate for Delphi studies, where expert opinions may vary substantially (Wan et al., 2014). In Round 2, the median was calculated for each statement, representing the central value of expert judgments, and providing a robust summary of the collective view, reflecting the level of relevance of each item. In line with prior Delphi research, a median value ≥ 4 indicates strong relevance (Diamond et al., 2014). Furthermore, for the purpose of redesign procurement models elements, statements can be ranked based on their median, from most to the least relevant, reflecting expert's perceived priorities (Keeney, Hasson and McKenna, 2010).

The IQR reflects the statistical dispersion of data around the median and consists of the 50% of values around it. In other words, the IQR measures the length of the interval that corresponds the centred 50% of data. In formula:

$$IQR=Q_3-Q_1 \quad (1)$$

Where:

- Q_1 is the first quartile, separating the lowest 25% of the observations from the rest

- Q_3 is the third quartile, separating the lowest 75% of the data from the highest 25%

To calculate the IQR, responses are first sorted in ascending order to identify both Q_1 and Q_3 , and then equation (1) is applied. Previous studies have underlined the suitability of the IQR for consensus measurement, as it offers a direct way to operationalize the degree of agreement without being affected by extreme values. Generally, a small IQR value indicates that experts' views are clustered closely together, signalling a higher degree of consensus, while a large IQR reveals greater divergence among participants. In this study: $IQR \leq 1$ is considered indicative of a high level of consensus; $1 < IQR \leq 1.5$ represents moderate consensus; and $IQR > 1.5$ indicates a lack of consensus, consistent with best practices for ordinal data on a 5-point scale (von der Gracht, 2012).

Kendall's W is a non-parametric statistic suitable for ordinal data and does not assume normality of distribution (von der Gracht, 2012). Its values range from 0, indicating no agreement, to 1, indicating complete agreement, providing a standardized measure of concordance across the panel. In general, values of $W \geq 0.7$ indicate strong agreement, $0.5 \leq W < 0.7$ indicate moderate agreement, $0.3 \leq W < 0.5$ indicate low agreement, and $W < 0.3$ indicate very weak or negligible agreement among panel members (Kendall, 1945; Paré et al., 2013; Schmidt, 1997). Since Kendall's W operates on ranked data rather than Likert-scale responses, expert ratings were first converted into rank (Conover, 1999). In cases of tied values, average ranks were assigned, following the practice described by Kendall (1945). In this study, the "Ranking Average" function in Microsoft Excel was used to convert individual expert ratings into ranking positions. The calculation of Kendall's W involved first the computation of the sum of squared deviations of rank sums (2):

$$S = \sum_{i=1}^n (R_i - \bar{R})^2 \quad (2)$$

Where R_i represents the sum of the ranks for item "i", and $\bar{R}$ is the mean of the rank sums (Legendre, 2022). Kendall's W statistic was then calculated by using the formula (3):

$$W = \frac{12S}{m^2(n^3 - n) - mT} \quad (3)$$

Where m denotes the number of experts, n the number of items, and T a correction factor accounting for tied ranks. The correction term T was calculated as (4):

$$T = \sum_{k=1}^g (t_k^3 - t_k) \quad (4)$$

Where t_k represents the number of tied ranks within each of the g groups of ties (Legendre, 2022).

In this study, a single rating was collected for each item related to motivations for integrating environmental sustainability in healthcare procurement; two separate ratings were collected for green and circular practices and related hindering factors, referring respectively to medical devices and pharmaceuticals; and three ratings per item were collected for procurement models redesign elements, one for each procurement model considered.

Computing a single Kendall's W across all items would require the assumption that all experts evaluated the full set of items included in the analysis. In this study, this condition is not always satisfied, particularly for practices and hindering factors, where the number of experts providing ratings is smaller than for motivations and procurement model redesign elements, as some participants were involved exclusively in the procurement of pharmaceuticals or of medical devices. Moreover, calculating a unique Kendall's W across all items would have required aggregating ratings referring to different conceptual dimensions, thereby reducing the interpretability of the coefficient.

Therefore, Kendall's W was computed on homogeneous subsets of items evaluated by the same panel of experts, divided into independent thematic blocks and, where applicable, for each product category or procurement model. This approach allowed for a consistent assessment of agreement among experts within each set of items and supports comparison across product categories and procurement models, in line with the research question and objective.

The combined use of these four indicators allowed for a comprehensive and methodologically robust assessment of consensus. While the mean and the median capture the central tendency, and the IQR quantifies the spread of responses at the item level, Kendall's W evaluate the overall agreement among all experts. This approach is consistent with recommendations for Delphi studies, ensuring that both individual item-level agreement and panel-wide concordance are systematically evaluated (Diamond et al., 2014; von der Gracht, 2012).

4. Results

The results of the Delphi study are structured according to the two research rounds and their complementary roles. First the findings from Round 1, which aimed to explore expert perspectives on environmental sustainability in healthcare procurement, are reported (Section 4.1). The results of Round 2 are then presented, focusing on the quantitative assessment of expert agreement through the use of both descriptive and inferential statistics, enabling a systematic validation and prioritisation of the proposed items (Section 4.2). The chapter concludes with a synthesis of the findings, integrating insights from both rounds to provide an overall interpretation of expert consensus and to support the identification of key implications for the redesign of healthcare procurement models across different product categories (Section 4.3).

4.1 Round 1 – Brainstorming and Narrowing Down

The first round of the Delphi study focused on understanding the motivations for integrating environmental sustainability into healthcare procurement, the green and circular practices currently implemented and related barriers, the sustainability-related obstacles influencing procurement decisions, the limitations of existing healthcare procurement models and the key elements suggested for their redesign.

Participants were asked to identify the two procurement models predominantly used within their organizations: the majority of experts operate within centralized procurement systems, either through national or regional central purchasing bodies, followed by autonomous procurement managed by single organizations and collaborative procurement involving multiple organizations. Only four experts reported the use of direct procurement without a tender, making this model less relevant for further investigation in Round 2. Overall, as shown in Figure 11, the sample reflects a combination of centralized, decentralized, and hybrid procurement models across healthcare product categories, which informed the selection of procurement models subsequently included in Round 2 for the evaluation of elements to be redesigned.

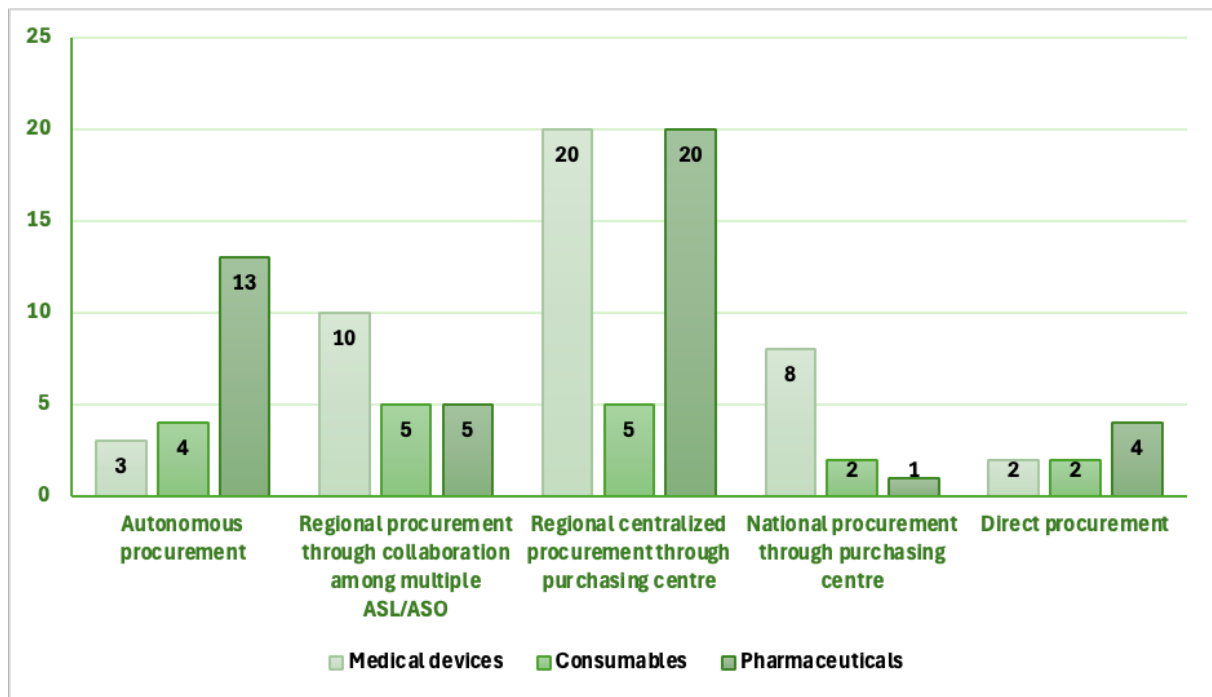


Figure 11 - Frequency of procurement models usage across healthcare product categories based on Round 1 responses

The qualitative analysis initially generated 153 raw statements from expert responses. After removing duplicates and consolidating overlapping contributions, 127 distinct items were identified. These items were then prioritised based on their frequency of occurrence across expert responses. Applying the pre-defined cut-off criteria for prioritisation, being cited by at least four respondents or by at least three respondents working for three different organizations, the list was reduced to 81 items, which were subsequently carried forward to Round 2 for the evaluation of relevance and consensus.

The analysis of Round 1 responses revealed a set of cross-category items, meaning that they were considered applicable across multiple healthcare product categories, which provide an overview of common motivations (Subsection 4.1.1), practices (Subsection 4.1.2), barriers, obstacles, limitations (Subsection 4.1.3), and potential redesign elements (Subsection 4.1.4) that experts perceive as critical for integrating sustainability into healthcare procurement processes.

4.1.1 Motivations to the integration of environmental sustainability in healthcare procurement

In terms of motivational drivers, experts highlighted environmental, normative, ethical, economic, and operational factors. Awareness of the environmental impact associated with high-volume purchases was identified as a motivator for adopting more sustainable practices, as reported by 2 experts (“Environmental impacts related to purchasing volumes”). In particular, the reduction of waste and the environmental impact of packaging were identified as central drivers

(“Reduction of environmental impacts from packaging”, “Waste reduction”, “Regulatory requirements for sustainability”), along with regulatory requirements embedded in procurement framework, cited in 7 responses (“Regulatory requirements for sustainability”). Moreover, individual ethical motivations, together with potential procedural efficiencies and economic benefits such as reduced waste management costs were reported by 7 experts, further reinforcing the incentives to integrate environmental sustainability into procurement decisions and suggesting that organisational approaches to sustainability remain relatively unstructured (“Ethical motivations”; “Reduction of waste disposal costs”; “Procedural benefits of sustainability”).

4.1.2 Sustainable and circular practices

4.1.2.1 Sustainable practices

Experts reported several sustainable practices aimed at optimizing logistics to reduce transport related emissions, improving the management of products and packaging throughout the supply chain, and ensuring compliance with minimum environmental criteria in tendering procedures. Among these, the integration of end-of-life costs into procurement decisions and the application of Minimum Environmental Criteria were among the most frequently cited practices, reported respectively by 6 and 7 experts (“Reduction of transport related emissions”, “Integration of end-of-life costs into procurement decisions”, “Application of Minimum Environmental Criteria in tendering procedures”, “Verification of compliance with Minimum Environmental Criteria”). Enabling factors that further support these sustainable practices include collaboration with suppliers, participation in technical working groups, and training initiatives, each mentioned in approximately 2 responses, which also contribute to increase awareness of environmental sustainability issues in the healthcare sector (“Sustainability training”, “Provincial green procurement networks”, “Participation in technical committees”).

These practices influence multiple steps of the procurement process. For example, integrating end-of-life costs and sustainability considerations during the needs identification and planning phases ensures that environmental objectives are embedded from the outset. Moreover, when selecting suppliers and finalizing contracts, environmental compliance becomes a key factor alongside traditional clinical and technical requirements. Finally, during delivery and performance monitoring, organisations track adherence to these criteria, evaluate supplier performance and gather insights for future procurement cycles.

4.1.2.2 Circular practices

Among circular practices that were found to be applicable across all healthcare product categories, the reuse of packaging was highlighted as one of the main transversal practices, reported by 2 experts (“Replacement of cardboard packaging with reusable crates”). The implementation of this practice can be considered during specification development and supplier selection, allowing organisations to define requirements and choose suppliers capable of providing reusable solutions. Additionally, during the evaluation and performance monitoring phase, indicators such as the reuse rate or the reduction in disposable materials can be measured to assess the effectiveness of these circular initiatives. Other circular practices are specific to individual product categories and are discussed in Sections 4.1.5 onwards.

4.1.3 Limiting factors to sustainable and circular procurement

Experts also identified several barriers to practices, obstacles influencing procurement decisions, and limitations of current procurement models that constrain sustainable procurement. These factors, which were often overlapping and sometimes difficult to separate, were initially analysed in a disaggregated form to preserve the richness of expert insights (Appendix 3), and subsequently aggregated and treated as a single block leading toward Round 2 as factors hindering the adoption of green and circular practices and sustainable procurement decisions (Appendix 4).

Economic barriers, such as the higher costs of sustainable products and strict budget constraints, respectively reported by 12 and 4 experts, frequently influence needs identification and planning, as financial limitations can prevent the organisation from considering environmental objectives from the outset (“Higher cost of sustainable products”, “Budget constraints”, “Cost-driven procurement priorities”). The adoption of sustainable practices is further restricted by cultural and organizational barriers, including low sustainability awareness and limited sustainability culture (“Lack of a sustainability culture” (14), “Insufficient sustainability-related competencies” (10), “Lack of procedural benefits” (1)), affecting both planning and specification development, and constraining the definition of sustainability requirements and the integration of environmental considerations into tender specifications.

Procedural and regulatory obstacles, such as the absence of binding legislative requirements, strategic vision, and the limited autonomy of local decision-makers (“Sector-specific regulatory constraints” (7), “Lack of a life-cycle perspective” (11), “Limited decision-making autonomy

in centralized tenders” (5)) were highlighted to negatively influence specification development, supplier selection, and contracting, restricting the ability of procurement teams to include environmental criteria and influence suppliers behaviour. These challenges are exacerbated by market related obstacles, cited in 4 responses, including the limited availability of sustainable suppliers and the difficulties for healthcare organisations in defining procurement requirements that effectively stimulate a more sustainable product innovation, which primarily affect market analysis and supplier selection, leading to a market largely driven by supplier-led initiatives (“Supply-driven market orientation”, “Limited availability of sustainable suppliers”).

Collectively, these barriers and obstacles are reflected in structural limitations of current healthcare procurement models, such as the limited presence or low weighting of environmental criteria in tenders, reported by 13 experts, and the insufficient involvement of technical and sustainability experts in tender committees, affecting tendering and evaluation processes (“Absence of sustainability related criteria in tender specifications”, “Lower weighting of sustainability criteria in tender evaluations”, “Lack of stakeholder involvement in tendering processes”).

4.1.4 Redesigning healthcare procurement models

Experts suggested several elements for the redesign of healthcare procurement models aimed at strengthening the role of environmental sustainability in decision-making. The most frequently cited proposals included assigning greater weight to environmental criteria in tenders and defining and separating sustainability requirements from quality criteria, reported by 12 and 6 experts (“Definition of sustainability criteria”, Separation of sustainability criteria from quality criteria in procurement decision-making”), which primarily influence specification development, supplier selection, and tendering, determining how products and suppliers are evaluated. Importantly, separating sustainability from quality criteria highlights the potential trade-offs between price and quality awards: while traditional procurement often prioritizes cost and technical performance, incorporating explicit sustainability requirements would allow decision-makers to balance environmental objectives with clinical and economic considerations.

Moreover, enhancing technical competencies within procurement teams, mentioned in 5 responses (“Integration of technical and sustainability related competences”) supports multiple procurement steps, including planning, specification development, and contracting, ensuring that staff can adequately define, assess, and enforce sustainability criteria. Additional proposals

include promoting a sustainability-oriented organizational culture and taking inspiration from best practices of international procurement models, cited by 4 and 2 experts (“Promotion of a sustainability-oriented culture”, “Take inspiration from foreign procurement”), shaping strategy definition and planning phases by embedding sustainability as a core organisation priority.

Finally, to address budget constraints, some experts suggested revising the allocation of procurement budgets to allow greater flexibility for decision-makers in selecting more sustainable products and suppliers, generally more expensive, a proposal reported by 1 expert (“Allocate larger budgets to sustainable suppliers”), influencing need identification and supplier selection and enabling the practical implementation of redesign elements without being limited by rigid financial thresholds.

After the analysis of cross-category items, Subsections 4.1.5, 4.1.6 and 4.1.7 focus on items that are specific to each healthcare product category, providing a detailed examination of category specific considerations emerging from Round 1. Items emerging from Round 1 that met the predefined cut-off criteria, are summarised in **Errore. L'origine riferimento non è stata trovata..** Conversely, the full list of items emerging from Round 1 is reported in Appendix 5.

Table 4 - Items included in Round 2

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEPA	Direct procurement (through direct award without tender)			
Motivations to the integration of environmental sustainability in healthcare procurement	Environmental drivers	Reduction of environmental impacts from packaging	Reducing packaging volumes and adopting sustainable packaging materials helps decrease waste generation, limit the need for incineration, and reduce emissions associated with waste disposal	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,F1,H1,H2,G1,G2,G3,J1,M1,M2,J2	12	6
		Waste reduction	Green and circular practices limit waste generation, for example by reducing the use of plastics in products and packaging, improving resource efficiency, and lowering overall environmental impacts	✓	✓	✓	✓	✓	✓		✓	J1,J2, K1, K2	4	2
	Regulatory drivers	Regulatory requirements for sustainability	Legislation and tender specifications increasingly include environmental sustainability criteria and requirements, encouraging the integration of sustainable practices into procurement decisions	✓	✓	✓	✓	✓	✓	✓	✓	A1,D1,E1,I1,K1,K2,O1	7	6
	Personal drivers	Ethical motivations	Sustainability in procurement may be driven by the personal values and ethical sensitivity of decision-makers, who promote sustainable practices in procurement processes regardless of regulatory obligations or constraints	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,C2,H1,I1,K1,K2	7	6
		Awareness of the environmental impact of products	The integration of sustainability into procurement is stimulated by decision-makers' awareness of the environmental impacts of products and by the organization's commitment to promoting sustainable operational practices	✓		✓	✓	✓	✓			C1, H1, O1	3	3
	Economic drivers	Economic sustainability of reusable products	The efficient use of reusable products should ensure a balance between economic and environmental sustainability by optimizing performance and extending product life cycles while reducing waste and costs	✓			✓	✓	✓	✓		A1,B1,B2,C1,H1,L1,L2,M1,M2	9	6
		Total cost of ownership (TCO)	Products should ensure environmental sustainability while remaining economically viable, considering costs across the entire life cycle	✓		✓	✓	✓	✓			C1, D1, J2	3	3
		Reduction of waste disposal costs	The adoption of sustainable or recyclable materials, waste reduction strategies, and more sustainable disposal practices helps decrease costs associated with the management and disposal of healthcare waste	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,D1,G1,G2,G3,H2,J1,L1,L2,J2	11	6
	Operational drivers	Logistics efficiency	Integrating sustainability into procurement enables optimization of storage, transportation management, and warehouse space utilization, reducing operational costs and improving overall supply chain efficiency	✓	✓	✓	✓	✓	✓	✓		G1,G2,G3,H1,H2,N1,N2	7	3
		Reduced workload for waste management	Waste management and disposal require time and human resources, increasing the internal workload associated with proper waste handling procedures	✓		✓	✓	✓	✓	✓		F1,G1,G2,G3	4	2

Table 4 (Continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEP A	Direct procurement (through direct award without tender)			
Sustainable practices	Supply chain optimization	Logistics optimization through centralization and aggregation	The centralization of warehouses and the aggregation of deliveries enable the rationalization of transport activities, reducing waste, costs, and energy consumption in healthcare logistics	✓		✓	✓	✓	✓	✓		A1,B1,B2,N1,N2	5	3
		Reduction of transport-related emissions	The adoption of low-emission vehicles and efficient transport planning reduces fuel consumption and the environmental impact of healthcare product distribution	✓	✓	✓	✓	✓	✓	✓		B1,B2,F1,H2,L1,L2,N1,N2	8	5
	Efficient management of products and packaging	Reduction of packaging	Sustainable packaging management (e.g. use of recycled or recyclable materials and reduced packaging volumes) decreases waste generation and environmental impacts along the healthcare supply chain	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,F1,G1,G2,G3,H2,K1,K2,L1,L2,M1,M2,O1	14	8
		Elimination of paper package leaflets for pharmaceuticals	Replacing paper package leaflets with digital solutions (e.g. QR codes) reduces paper waste and the overall environmental impact of pharmaceuticals			✓			✓		✓	K1,K2,N1,N2	4	2
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Integration of end-of-life costs into procurement decisions	The inclusion of end-of-life and disposal costs in purchasing decisions helps reduce waste and operational costs	✓	✓	✓	✓	✓	✓	✓		B1,B2,F1,H2,M1,M2	6	4
		Application of Minimum Environmental Criteria in tendering procedures	The application of Minimum Environmental Criteria in tendering procedures ensures compliance with minimum environmental sustainability standards for procured products	✓	✓	✓	✓	✓	✓	✓	✓	J1,K1,K2,L1,L2,M1,M2	7	4
		Environmental assessment of suppliers and products	Products and suppliers are selected based on compliance with environmental standards, recognized certifications, and the use of sustainable materials	✓	✓	✓	✓	✓	✓			E1,H2,M1,M2,J2	5	4
Circular practices	Material reduction	Procurement of products made from recycled materials	Purchasing products made from recycled materials (e.g. recycled paper) helps reduce environmental impacts and supports the circular economy		✓		✓		✓		✓	J1,K1,K2,L1,L2	5	3
	Recycle	Procurement of recyclable containers	The procurement of containers made from recyclable materials contributes to reducing waste volumes and improves the sustainability of materials management by facilitating proper end-of-life disposal			✓			✓		✓	K1,K2,N1,N2	4	2
	Reuse	Integration of reusable medical devices	Promoting the use of reusable devices (e.g. surgical instruments or operating room materials) through safe and controlled sterilization processes extends product lifecycles, reduces waste, and lowers the environmental impact of healthcare procedures	✓			✓	✓	✓	✓		A1,D1,E1,H1,H2,I1,M1,M2,J2	9	7

Table 4 (Continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEP A	Direct procurement (through direct award without tender)			
Limiting factors to sustainable and circular practices and sustainable procurement decisions	Clinical preferences	Clinicians' preference for single-use devices	Clinicians tend to prefer single-use devices for reasons related to safety, convenience, and perceived effectiveness, limiting the adoption of reusable alternatives	✓			✓	✓	✓	✓		A1,C1,E1,G1,G2,G3,H1,H2,L1,L2,M1,M2,J2	13	8
	Managerial barriers	Complexity in managing reusable devices	The introduction of reusable devices increases operational and logistical complexity, particularly with regard to sterilization pathways	✓			✓	✓	✓		✓	A1,D1,E1,H2,K1,K2,J2	7	6
		Legal liability related to the sterilization of reusable devices	Legal responsibility associated with the sterilization of reusable devices makes single-use solutions a simpler option from an operational perspective	✓				✓	✓			E1,H2,M1,M2	4	3
	Economic barriers	Higher cost of sustainable products	Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption	✓	✓	✓	✓	✓	✓	✓		B1,B2,C1,C2,E1,H2,K1,K2,L1,L2,N1,N2	12	7
		Budget constraints	Budget limitations reduce procurement flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints	✓	✓	✓	✓	✓	✓	✓		D1,E1,H1,I1	4	4
		Cost-driven procurement priorities	Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices.	✓	✓	✓	✓	✓	✓	✓	✓	C2,D1,E1,G1,G2,G3,H1,I1,K1,K2,M1,M2,N1,N2	14	9
	Cultural barriers	Resistance to change	Conservative mindsets and resistance to change among healthcare professionals hinder the adoption of sustainable practices	✓		✓		✓	✓			D1,H2,L1,L2,M1,M2,O1	7	5
		Lack of a sustainability culture	Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement	✓	✓	✓	✓	✓	✓	✓	✓	C2,E1,H1,K1,K2,I1,I1,L1,L2,M1,M2,N1,N2,O1	14	10
	Lack of sustainability-related competencies	Insufficient sustainability-related competencies	A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes	✓	✓	✓	✓	✓	✓	✓	✓	A1,C1,C2,E1,H2,I1,L1,L2,M1,M2	10	7
	Organizational barriers	Sustainability not considered a priority	The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority.	✓		✓	✓	✓	✓	✓		B1,B2,C2,G1,G2,G3,N1,N2	8	4
	Procedural barriers	Sustainability requirements not effectively evaluated in tender awards	Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions	✓	✓	✓	✓		✓		✓	E1,H1,K1,K2,J1,M1,M2	7	5
	Regulatory obstacles	Sector-specific regulatory constraints	Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations	✓		✓	✓	✓	✓	✓		E1,F1,H1,K1,K2,N1,N2	7	5
		Lack of binding sustainability-related regulations	The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects	✓	✓	✓	✓	✓	✓	✓		A1,E1,C1,G1,G2,G3,H1,L1,L2	9	6
	Organizational obstacles	Lack of standardization in sustainable procurement	The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria	✓		✓	✓	✓	✓	✓		C1,E1,G1,G2,G3,I1,K1,K2,O1	9	6
	Economic obstacles	Low base prices in tenders	Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers	✓		✓	✓	✓	✓	✓		B1,B2,M1,M2	4	2
	Market obstacles	Supply-driven market orientation	Sustainable innovation is mainly driven by suppliers, while healthcare organizations do not always define requirements that stimulate sustainable product innovation	✓	✓	✓	✓	✓	✓	✓		L1,L2,M1,M2	4	2
	Procedural obstacles	Lack of a life-cycle perspective	The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions	✓	✓	✓	✓	✓	✓	✓		C1,D1,E1,G1,G2,G3,H2,K1,K2,L1,L2	11	7
		Limited decision-making autonomy in centralized tenders	In centralized procurement procedures, local decision-makers have limited autonomy; established criteria must accommodate the heterogeneous levels of environmental awareness and preparedness across participating organizations, limiting the adoption of more sustainable solutions	✓	✓	✓	✓	✓	✓	✓		G1,G2,G3,H2,I1	5	3
	Procedural limitation	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	✓	✓	✓	✓	✓	✓	✓	✓	A1,B1,B2,D1,F1,G1,G2,G3,H2,I1,J2,L1,L2	13	8

Table 4 (Continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEP A	Direct procurement (through direct award without tender)			
Elements to redesign in current procurement models	Revision of tender parameters	Definition of sustainability criteria	Sustainability requirements to be included as evaluation criteria in tender specifications should be clearly defined in order to guide procurement decisions toward more sustainable practices.	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,C1,D1,G1,G2,G3,L1,L2,M1,M2,J2	12	7
		Allocation of sustainability-related scores in tender specifications	Environmental criteria should be assigned a significant weight in tender scoring systems, effectively incentivizing suppliers to develop sustainable solutions, even if this may potentially reduce the number of eligible suppliers	✓	✓	✓	✓	✓	✓	✓		C1,H1,I1,M1,M2	5	4
		Separation of environmental sustainability criteria from quality criteria in procurement decision-making	Environmental sustainability should be considered as an autonomous evaluation criterion, rather than being embedded within quality criteria, and should be assigned an appropriate weight in the award process so as to influence procurement decisions alongside price and quality	✓	✓	✓	✓		✓	✓	✓	E1,G1,G2,G3,K1,K2	6	3
	Greater awareness in procurement decisions	Integration of technical and sustainability-related competencies	Strengthening the role of clinical engineers and integrating professionals with environmental sustainability expertise within technical committees or working groups involved in tender design would promote a multidisciplinary approach capable of balancing technical efficiency and environmental objectives	✓	✓	✓	✓	✓	✓	✓	✓	A1,C1,J1,L1,L2	5	4
		Promotion of a sustainability-oriented culture	The implementation of initiatives and training programs aimed at increasing awareness of the environmental impacts of the healthcare sector and encouraging sustainability-oriented purchasing decisions	✓	✓	✓	✓	✓	✓	✓		E1,I1,M1,M2	4	3

4.1.5 Medical devices

Environmental sustainability in medical device procurement emerges as strongly shaped by a tension between environmental objectives, clinical preferences, and operational feasibility.

From a **motivational** perspective, economic sustainability, with 9 citations, plays a central role with several experts highlighting the relevance of life-cycle considerations in procurement decisions and emphasizing that the efficient use of reusable medical devices can optimize performance and reduce both waste and long-term costs (“Economic sustainability of reusable products”). In addition, although less frequently mentioned, Product-Service System (PSS) models were cited by 2 experts and associated with potential economic advantages, such as reduced inventory requirements and a lower risk of product obsolescence, as well as a reduction of technological waste (“Economic benefits of the Product-Service System”, “Reduction of technological waste through the Product-Service System”).

Circular **practices** such as the integration of reusable devices emerged as a key practice for medical devices, reported by 9 experts. Supported by safe and controlled sterilization processes, reusable devices emerged as a mean to reduce waste generation, and the environmental impacts associated with single-use devices (“Integration of reusable medical devices”). Additional sustainability related practices include the selection of products without toxic residues to protect healthcare workers’ health, as well as initiatives aimed at increasing the economic awareness of medical staff, each mentioned in approximately 2 responses, thereby fostering more informed and sustainability-oriented usage decisions (“Non-toxic products”, “Economic awareness among medical staff”). The refurbishment of unused devices was also mentioned as an example of circular practice, although its practical implementation remains limited (“Refurbishment of unused devices”).

However, the medical devices category is characterized by a dense and interconnected set of **barriers**. A dominant barrier identified by 13 experts is the strong clinical preference for single-use devices, driven by concerns related to safety, convenience, and perceived effectiveness, which significantly limits the adoption of reusable solutions, even when environmental preferable alternatives are available (“Clinicians’ preference for single-use devices”). Operational and managerial barriers further constrain the transition toward circular practices: the introduction of multi-use devices increases logistical and organizational complexity, particularly with regard to sterilization pathways, availability management, and legal responsibility for sterilization

processes, as reported by 7 experts (“Complexity in managing reusable devices”). Additionally, circular solutions appear to be not always economically advantageous, especially for low unit-cost devices or when sterilization processes are outsourced, reducing the financial attractiveness of reusable options, as highlighted by 3 experts (“Lack of economic convenience of circular practices”). These challenges, compounded by market dynamics, where suppliers tend to promote single-use products, and by the need to maintain single-use devices as backup solutions to prevent stock-out, limit the feasibility of a full transition to reusable systems (“Supplier orientation toward single-use devices”, “Single-use devices as support to reusable devices”).

As regard regulatory **obstacles**, 1 expert noted that despite European regulations allowing the reprocessing and reuse of single-use devices under certain conditions, national regulations in Italy currently restrict such practices, creating uncertainty and limiting the adoption of circular solutions (“EU-Italy regulatory inconsistency on single-use devices reuse”). The absence of a clear and supportive regulatory framework for reusable devices represents a significant obstacle to sustainability related innovation in medical device procurement. Also, experts noted that increased bureaucratic complexity, particularly in tenders involving multi-products lots, makes it more difficult to integrate sustainability criteria due to limited administrative and technical competencies, as mentioned in 1 response (“Increased bureaucratic complexity in multi-product lot tenders”).

Finally, among the elements proposed for the **redesign** of procurement models related to medical devices, greater contractual flexibility was suggested by 1 expert as a way to better accommodate sustainability-oriented solutions, particularly through contractual arrangements such as availability-based contracts, in which suppliers retain responsibility for maintenance and functionality, supporting organizations in more sustainable procurement outcomes in a highly regulated and safety-sensitive product category (“Availability contract”).

4.1.6 Consumables

The procurement of consumables is strongly influenced by the intrinsic characteristics of the products, which in some cases facilitate the integration of environmental sustainability criteria due to the materials used and the absence of strict clinical or regulatory constraints, compared to other healthcare product categories such as pharmaceuticals, creating opportunities for experimenting with sustainable alternatives without compromising safety or performance (“Product characteristics facilitating sustainability”).

Material-related strategies were cited as examples of already implemented **practices** to support the implementation of circular economy principles in healthcare procurement. In particular, the procurement of products made from recycled materials, such as recycled paper, as well as compostable products that can be transformed into compost at the end of their life cycle, as highlighted by 2 experts, allow to reduce waste volumes and the environmental impact of disposal (“Procurement of compostable products”, “Procurement of products made from recycled materials”).

On the other hand, managerial **barriers** were reported by 1 expert in relation to the use of recycled or alternative materials not supplied by original manufacturers, which may lack formal guarantees or maintenance services, discouraging procurement professional from selecting more sustainable options, even when their environmental performance is superior (“Lack of warranty or maintenance for recycled non-clinical supplies”).

Lastly, **limitations** were identified at the level of procurement procedures. Rigid tender structures, imposing fixed weightings between price and quality were cited by 2 experts, as restricting the flexibility needed to adequately integrate and valorise sustainability criteria into procurement decisions, as they must fit within predefined evaluation schemes that prioritize traditional economic and technical parameters (“Rigid price/quality weighting”).

4.1.7 Pharmaceuticals

Environmental sustainability in pharmaceutical procurement emerges as constrained by regulatory requirements and intrinsic product characteristics.

From a **motivational** perspective, environmental considerations were mentioned in relation to upstream production processes: reducing the environmental impact of manufacturing activities for chemically complex products was perceived by 1 expert as a relevant lever for improving overall sustainability performance (“Less environmentally impactful production processes”). Economic motivations were instead mainly associated with efficiency gains in the preparation and management of high-value drugs, such as oncology medicines, where optimizing production processes can significantly reduce waste while improving cost-efficiency, as reported by 2 experts (“Economic efficiency in high-value pharmaceuticals”).

Looking at sustainable **practices**, bulk procurement was highlighted by 2 experts as a practice capable of reducing the number of packages, minimizing packaging materials, and

optimizing transportation, generating both environmental and economic benefits (“Bulk procurement”). Similarly, practices such as the elimination of paper leaflets through digital solutions such as QR codes, the reduction in the use of vials through on-site drug preparation, and the unbundling of medicines to provide patients only with the quantities strictly required were cited by 2 experts (“Elimination of paper package leaflets for pharmaceuticals”, “Reduction in the use of pharmaceuticals vials”, “Pharmaceutical unpackaging (unit-dose dispensing)”). Circular practices were also mentioned by at least 2 experts, including the use of recyclable containers and the reduction of plastic packaging in favour of more sustainable material, as well as the exchange of pharmaceuticals close to expiration dates between healthcare organizations to avoid unnecessary waste (“Procurement of recyclable containers”, “Reduction in plastic use”, “Pharmaceuticals circularity”).

Despite these opportunities, pharmaceutical procurement is characterized by significant **barriers** mainly related to the intrinsic characteristics of pharmaceutical products and their production processes. These barriers, as reported by 1 expert, limit the feasibility of alternative materials, eco-design solutions, or packaging innovations without compromising safety, stability, or regulatory compliance (“Sustainability constrained by pharmaceutical product characteristics”). Also, an inefficient order management was identified in 1 response as a procedural obstacle leading to frequent and fragmented orders, increasing transportation needs and associated environmental impacts (“Inefficient order management”).

Finally, as regard **limitations** of current procurement models, a limited flexibility in integrating environmental sustainability criteria was highlighted by 2 experts. In fact, even within centralized or collaborative procurement frameworks, the rigid regulatory environment was perceived as reducing the ability to meaningfully incorporate sustainability-related considerations into supplier selection and award criteria (“Limited flexibility in applying sustainability criteria”).

4.2 Round 2 – Ranking and consensus building

While Round 1 captured the breadth and richness of expert perspectives, Round 2 aimed to quantitatively assess the relevance of the items and the convergence among the panel, moving from exploration to structured prioritisation. Experts were asked to evaluate the proposed items using a 5-point Likert scale. In line with the objectives of identifying areas of convergence and strengthening shared priorities across the panel, the results were analysed using both descriptive statistics (Subsection 4.2.1) and inferential statistic (Subsection 4.2.2).

4.2.1 Descriptive statistics: Mean, Median, and IQR calculation

Responses were analysed using mean, median and IQR, in order to identify both the perceived relevance and the level of consensus across the panel for each item. In line with the predefined decision rules, items with median values ≥ 4 were considered highly relevant, while an IQR ≤ 1 was interpreted as evidence of consensus among experts.

With respect to **motivations** for integrating environmental sustainability into healthcare procurement, all items achieved median values of 4 or 5, with consistently low IQR values, indicating strong agreement among experts. In particular, motivations related to sustainable management of reusable devices, reduced workload related to waste management, packaging environmental impacts, regulatory drivers, and waste reduction emerged as highly prioritised, reflecting a shared recognition of both environmental and economic incentives for sustainable procurement decisions. The only exception was represented by ethical motivations, for which an IQR = 1,5 indicated a fragmented and weakly institutionalised approach to sustainability at the organisational level, suggesting that these motivations derive more from individual rather than corporate values. Results are presented in Table 5.

Table 5 - Descriptive statistics for motivations to integrate environmental sustainability in healthcare procurement

Theme	Item	Mean	Median	IQR	Consensus
Motivations to the integration of environmental sustainability in healthcare procurement	Sustainable management of reusable medical devices: The efficient use of reusable medical devices should ensure a balance between economic and environmental sustainability by optimizing performance, extending product lifespan, and reducing waste and costs.	4,84	5	0	Yes
	Reduced workload related to waste management: The management and disposal of healthcare waste require time and resources, increasing the internal workload associated with proper waste handling.	4,74	5	0,5	Yes
	Reduction of the environmental impacts of packaging: The reduction of packaging volumes and the adoption of sustainable packaging materials help decrease waste generation, reduce the need for incineration, and limit emissions associated with waste disposal.	4,63	5	0,5	Yes
	Presence of regulatory requirements related to sustainability: Legislation and tender specifications that include environmental criteria encourage the integration of sustainability into procurement decision-making.	4,58	5	1	Yes
	Awareness of the environmental impact of products: Decision-makers' awareness of the environmental impact of products, together with the organization's commitment, fosters the adoption of sustainable procurement practices.	4,58	5	1	Yes
	Logistics optimization: Integrating sustainability into procurement enables the optimization of storage, transportation, and warehouse space, reducing operational costs and improving supply chain efficiency.	4,53	5	1	Yes
	Waste reduction: Green and circular practices reduce waste generation, thereby improving resource efficiency and overall environmental performance.	4,42	5	1	Yes
	Total cost of ownership (TCO): Products should be environmentally sustainable and economically viable when considering costs across their entire life cycle.	4,37	4	1	Yes
	Reduction of waste disposal costs: The procurement of sustainable or recyclable materials and more sustainable disposal practices contributes to reducing healthcare waste management costs.	4,26	4	1	Yes
	Ethical motivations: The individual environmental awareness and ethical sensitivity of decision-makers promote the integration of sustainability into procurement processes, independently of regulatory obligations.	4,11	4	1,5	No

Regarding green and circular **practices**, a high degree of convergence was observed for both medical devices and pharmaceuticals, particularly for practices related to reduction of transport emissions, the application of environmental criteria in tendering processes, logistics optimisation and the environmental evaluation of suppliers and products. These items consistently reached the relevance threshold and showed limited dispersion in responses. However, for medical devices, the integration of reusable devices had an $IQR = 2$, suggesting a more heterogeneous assessment among experts, reflecting the operational, regulatory and organisational tensions highlighted in Round 1. For pharmaceuticals, instead, the elimination of paper package leaflets reached a median value of 3, introducing potential difficulties in integrating this practice.

A similarly strong pattern emerged for limiting factors. Most **barriers** identified in Round 1 were confirmed as highly relevant in Round 2, with median values predominantly ≥ 4 and low IQRs, signalling substantial consensus. Economic constraints, budget limitations, price-oriented procurement practices and insufficient integration of sustainability criteria in tender evaluation were consistently recognised as major obstacles. Organisational and cultural barriers, such as limited life-cycle perspective, lack of sustainability-related competences and resistance to change, were also broadly acknowledged across both medical devices and pharmaceuticals

procurement. Notably, for pharmaceuticals, only one limiting factor, namely sector-specific regulatory constraints, did not reach consensus ($IQR = 2$), suggesting heterogeneous perceptions among experts regarding the extent to which existing regulatory frameworks hinder the integration of environmental sustainability. Results are presented in Table 6 and Table 7

Table 6 - Descriptive statistics for sustainable and circular practices related to medical devices and pharmaceuticals

Theme	Product category	Item	Mean	Median	IQR	Consensus
Sustainable and circular practices	Medical devices	Reduction of packaging: Sustainable packaging management (e.g. use of recycled or recyclable materials and reduced packaging volumes) decreases waste generation and environmental impacts along the healthcare supply chain	4,72	5	0,75	Yes
		Reduction of transport-related emissions: The adoption of low-emission vehicles and efficient transport planning reduces fuel consumption and the environmental impact of healthcare product distribution	4,56	5	1	Yes
		Application of Minimum Environmental Criteria in tendering procedures: The application of Minimum Environmental Criteria in tendering procedures ensures compliance with minimum environmental sustainability standards for procured products	4,56	5	1	Yes
		Logistics optimization through centralization and aggregation: The centralization of warehouses and the aggregation of deliveries enable the rationalization of transport activities, reducing waste, costs, and energy consumption in healthcare logistics	4,39	4,5	1	Yes
		Procurement of recyclable containers: The purchase of containers made from recyclable materials contributes to reducing waste volumes and improves the sustainability of materials management by facilitating proper end-of-life disposal	4,39	4,5	1	Yes
		Integration of end-of-life costs into purchasing decisions: The inclusion of end-of-life and disposal costs in purchasing decisions helps reduce waste and operational costs	4,28	4	1	Yes
		Environmental assessment of suppliers and products: Products and suppliers are selected based on compliance with environmental standards, recognized certifications, and the use of sustainable materials	4,28	4	1	Yes
		Procurement of products made from recycled materials: Purchasing products made from recycled materials (e.g. recycled paper) helps reduce environmental impacts and supports the circular economy	4,17	4	0,75	Yes
		Integration of reusable medical devices: Promoting the use of reusable devices (e.g. surgical instruments or operating room materials) through safe and controlled sterilization processes extends product lifecycles, reduces waste, and lowers the environmental impact of healthcare procedures	4,06	4	2	No
	Pharmaceuticals	Reduction of transport-related emissions: The adoption of low-emission vehicles and efficient transport planning reduces fuel consumption and the environmental impact of healthcare product distribution	4,47	5	1	Yes
		Reduction of packaging: Sustainable packaging management (e.g. use of recycled or recyclable materials and reduced packaging volumes) decreases waste generation and environmental impacts along the healthcare supply chain	4,47	5	1	Yes
		Application of Minimum Environmental Criteria in tendering procedures: The application of Minimum Environmental Criteria in tendering procedures ensures compliance with minimum environmental sustainability standards for procured products	4,29	4	1	Yes
		Procurement of recyclable containers: The purchase of containers made from recyclable materials contributes to reducing waste volumes and improves the sustainability of materials management by facilitating proper end-of-life disposal	4,18	4	1	Yes
		Logistics optimization through centralization and aggregation: The centralization of warehouses and the aggregation of deliveries enable the rationalization of transport activities, reducing waste, costs, and energy consumption in healthcare logistics	4,12	5	1	Yes
		Environmental assessment of suppliers and products: Products and suppliers are selected based on compliance with environmental standards, recognized certifications, and the use of sustainable materials	4,00	4	0	Yes
		Integration of end-of-life costs into purchasing decisions: The inclusion of end-of-life and disposal costs in purchasing decisions helps reduce waste and operational costs	3,53	4	1	Yes
		Elimination of paper package leaflets for pharmaceuticals: Replacing paper package leaflets with digital solutions (e.g. QR codes) reduces paper waste and the overall environmental impact of pharmaceuticals	3,41	3	1	Yes

Table 7 - Descriptive statistics for limiting factors related to medical devices and pharmaceuticals

Theme	Product category	Item	Mean	Median	IQR	Consensus
Limiting factors	Medical devices	Low base prices in tenders: Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers	4,50	5	1	Yes
		Budget constraints: Budget limitations reduce purchasing flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints	4,44	4,5	1	Yes
		Higher cost of sustainable products: Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption	4,39	4,5	1	Yes
		Lack of standardization in sustainable procurement: The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria	4,39	4	1	Yes
		Absence of sustainability-related quality criteria in tender specifications: Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	4,39	4	1	Yes
		Cost-driven procurement priorities: Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices.	4,33	4,5	1	Yes
		Sustainability not considered a priority: The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority.	4,28	4	1	Yes
		Sustainability requirements not effectively evaluated in tender awards: Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions	4,28	4	1	Yes
		Legal liability related to the sterilization of reusable devices: Legal responsibility associated with the sterilization of reusable devices makes single-use solutions a simpler option from an operational perspective	4,17	4,5	1	Yes
		Lack of binding sustainability-related regulations: The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects	4,17	4	1	Yes
		Lack of a life-cycle perspective: The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions	4,11	4	0,75	Yes
		Clinicians' preference for single-use devices: Clinicians tend to prefer single-use devices for reasons related to safety, convenience, and perceived effectiveness, limiting the adoption of reusable alternatives	4,06	4	0,75	Yes
		Complexity in managing reusable devices: The introduction of reusable devices increases operational and logistical complexity, particularly with regard to sterilization pathways	4,06	4	1	Yes
		Limited decision-making autonomy in centralized tenders: In centralized procurement procedures, local decision-makers have limited autonomy; established criteria must accommodate the heterogeneous levels of environmental awareness and preparedness across participating organizations, limiting the adoption of more sustainable solutions	4,06	4	1	Yes
		Insufficient sustainability-related competencies: A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes	4,00	4	0	Yes
		Supply-driven market orientation: Sustainable innovation is mainly driven by suppliers, while healthcare organizations do not always define requirements that stimulate sustainable product innovation	3,94	4	0	Yes
		Sector-specific regulatory constraints: Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations	3,72	4	1	Yes
		Resistance to change: Conservative mindsets and resistance to change among healthcare professionals hinder the adoption of sustainable practices	3,67	4	1	Yes
		Lack of a sustainability culture: Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement	3,67	4	0	Yes
	Pharmaceuticals	Cost-driven procurement priorities: Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices.	4,53	5	1	Yes
		Higher cost of sustainable products: Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption	4,29	4	1	Yes
		Budget constraints: Budget limitations reduce purchasing flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints	4,29	4	1	Yes
		Sustainability not considered a priority: The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority.	4,29	4	1	Yes
		Absence of sustainability-related quality criteria in tender specifications: Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	4,29	4	1	Yes
		Sustainability requirements not effectively evaluated in tender awards: Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions	4,18	4	1	Yes
		Lack of binding sustainability-related regulations: The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects	4,18	4	1	Yes
		Lack of standardization in sustainable procurement: The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria	4,12	4	0	Yes
		Low base prices in tenders: Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers	4,12	4	1	Yes
		Insufficient sustainability-related competencies: A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes	3,88	4	0	Yes
		Sector-specific regulatory constraints: Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations	3,88	4	2	No
		Lack of a life-cycle perspective: The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions	3,88	4	1	Yes
		Supply-driven market orientation: Sustainable innovation is mainly driven by suppliers, while healthcare organizations do not always define requirements that stimulate sustainable product innovation	3,82	4	1	Yes
		Limited decision-making autonomy in centralized tenders: In centralized procurement procedures, local decision-makers have limited autonomy; established criteria must accommodate the heterogeneous levels of environmental awareness and preparedness across participating organizations, limiting the adoption of more sustainable solutions	3,65	4	0	Yes
		Lack of a sustainability culture: Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement	3,53	4	0	Yes
		Resistance to change: Conservative mindsets and resistance to change among healthcare professionals hinder the adoption of sustainable practices	3,41	4	1	Yes

Finally, the analysis of elements requiring **redesign** across different procurement models, namely centralised regional or national procurement, procurement through inter-organisations collaboration, and autonomous procurement, revealed a high level of alignment in expert evaluations. Across all models, the definition of clear sustainability criteria, the assignment of explicit weights to environmental aspects in tender evaluation, the integration of multidisciplinary competences and above all the promotion of sustainability culture were all rated as highly relevant with median values that consistently met the relevance threshold, and IQR values that generally indicated the presence of consensus, suggesting that these redesign priorities are perceived as broadly applicable regardless of the procurement configuration. Results are presented in Table 8.

Table 8 - Descriptive statistics for elements to redesign across centralised, collaborative and autonomous procurement model

Theme	Procurement model	Item	Mean	Median	IQR	Consensus
Elements to redesign in current procurement models	Centralized national or regional procurement	Promotion of a sustainability-oriented culture: The implementation of initiatives and training programs aimed at increasing awareness of the environmental impacts of the healthcare sector and encouraging sustainability-oriented purchasing decisions	4,58	5	1	Yes
		Definition of sustainability criteria: Sustainability requirements to be included as evaluation criteria in tender specifications should be clearly defined in order to guide procurement decisions toward more sustainable practices.	4,47	4	1	Yes
		Integration of technical and sustainability-related competencies: Strengthening the role of clinical engineers and integrating professionals with environmental sustainability expertise within technical committees or working groups involved in tender design would promote a multidisciplinary approach capable of balancing technical efficiency and environmental objectives	4,32	4	1	Yes
		Allocation of sustainability-related scores in tender specifications: Environmental criteria should be assigned a significant weight in tender scoring systems, effectively incentivizing suppliers to develop sustainable solutions, even if this may potentially reduce the number of eligible suppliers	4,21	4	1	Yes
		Separation of environmental sustainability criteria from quality criteria in procurement decision-making: Environmental sustainability should be considered as an autonomous evaluation criterion, rather than being embedded within quality criteria, and should be assigned an appropriate weight in the award process so as to influence procurement decisions alongside price and quality	4,21	4	1	Yes
	Procurement through inter-organisations collaboration	Promotion of a sustainability-oriented culture: The implementation of initiatives and training programs aimed at increasing awareness of the environmental impacts of the healthcare sector and encouraging sustainability-oriented purchasing decisions	4,53	5	1	Yes
		Definition of sustainability criteria: Sustainability requirements to be included as evaluation criteria in tender specifications should be clearly defined in order to guide procurement decisions toward more sustainable practices.	4,32	4	1	Yes
		Integration of technical and sustainability-related competencies: Strengthening the role of clinical engineers and integrating professionals with environmental sustainability expertise within technical committees or working groups involved in tender design would promote a multidisciplinary approach capable of balancing technical efficiency and environmental objectives	4,26	4	1	Yes
		Allocation of sustainability-related scores in tender specifications: Environmental criteria should be assigned a significant weight in tender scoring systems, effectively incentivizing suppliers to develop sustainable solutions, even if this may potentially reduce the number of eligible suppliers	4,11	4	0,5	Yes
		Separation of environmental sustainability criteria from quality criteria in procurement decision-making: Environmental sustainability should be considered as an autonomous evaluation criterion, rather than being embedded within quality criteria, and should be assigned an appropriate weight in the award process so as to influence procurement decisions alongside price and quality	4,11	4	0	Yes
	Autonomous procurement	Promotion of a sustainability-oriented culture: The implementation of initiatives and training programs aimed at increasing awareness of the environmental impacts of the healthcare sector and encouraging sustainability-oriented purchasing decisions	4,42	5	1	Yes
		Definition of sustainability criteria: Sustainability requirements to be included as evaluation criteria in tender specifications should be clearly defined in order to guide procurement decisions toward more sustainable practices.	4,26	4	1	Yes
		Integration of technical and sustainability-related competencies: Strengthening the role of clinical engineers and integrating professionals with environmental sustainability expertise within technical committees or working groups involved in tender design would promote a multidisciplinary approach capable of balancing technical efficiency and environmental objectives	4,16	4	1	Yes
		Allocation of sustainability-related scores in tender specifications: Environmental criteria should be assigned a significant weight in tender scoring systems, effectively incentivizing suppliers to develop sustainable solutions, even if this may potentially reduce the number of eligible suppliers	4,05	4	1	Yes
		Separation of environmental sustainability criteria from quality criteria in procurement decision-making: Environmental sustainability should be considered as an autonomous evaluation criterion, rather than being embedded within quality criteria, and should be assigned an appropriate weight in the award process so as to influence procurement decisions alongside price and quality	4,05	4	0	Yes

4.2.2 Inferential statistics: Kendall's W coefficient of concordance

In addition to assessing item relevance and consensus via descriptive statistics, the relative prioritisation of items within each thematic area was evaluated using the Kendall's W coefficient of concordance. This coefficient measures the degree of agreement among experts regarding the rank ordering of items, rather than their absolute variance. In particular, a W value of 0 indicates no agreement, while a value of 1 indicates complete consensus on item ranking. Following the interpretation threshold introduced in the methodology section, Table 9 summarises the classification of the degree of concordance measured by Kendall's W coefficient (Schmidt, 1997).

Table 9 - Classification of Kendall's W values and corresponding degree of concordance

$W < 0.10$	Absent or negligible concordance
$0.10 \leq W < 0.30$	Weak concordance
$0.30 \leq W < 0.50$	Moderate concordance
$0.50 \leq W < 0.7$	Good concordance
$W \geq 0.7$	Very strong concordance

Across the panel, Kendall's W values were generally low. For motivations driving the integration of environmental sustainability into healthcare procurement, W value was of 0.12. Similarly, for green and circular practices, W values were 0.13 for medical devices and 0.26 for pharmaceuticals, reflecting diverse expert opinions on which practices should be prioritised. For limiting factors, W values remained weak, at 0.10 and 0.12 for medical devices and pharmaceuticals, respectively. Finally, elements requiring redesign across different procurement models showed W values below 0.10, indicating almost absent concordance on the prioritisation of redesign actions, even though median values consistently indicated high relevance and low IQRs signalled agreement on their importance.

Overall, the Kendall's W analysis highlights that while experts agree on the relevance of items within each thematic area, there is considerable variability in how they prioritise these items relative to one another, underscoring the multidimensional nature of sustainable procurement decision-making in healthcare and reflecting differences in professional background, organisational contexts, and product-category specific challenges. Results for Kendall's W coefficient are reported in Table 10.

Table 10 - Kendall's W coefficient of concordance results

Theme	Product category/ Procurement model	Kendall's W	Degree of concordance
Motivations to the integration of environmental sustainability in healthcare procurement	/	0.12	Weak concordance
Sustainable and circular practices	Medical devices	0.13	Weak concordance
	Pharmaceuticals	0.26	
Limiting factors	Medical devices	0.10	Weak concordance
	Pharmaceuticals	0.12	
Elements to redesign in current procurement models	Centralized national or regional procurement	0.06	Absent or negligible concordance
	Procurement through inter-organisations collaboration	0.10	Weak concordance
	Autonomous procurement	0.07	Absent or negligible concordance

4.3 Comparative analysis

While the previous section focused on the identification, validation and prioritisation of motivations, sustainable and circular practices, limiting factors, and redesign elements, this comparative analysis aims to highlight convergences and divergences emerging from the expert panel when considering different healthcare product categories and procurement models.

In particular, Subsection 4.3.1 compares medical devices, consumables, and pharmaceuticals, focusing on similarities and differences in perceived motivations, applicable green and circular practices, and limiting factors, while Subsection 4.3.2 examines whether redesign priorities vary across procurement models, including centralised national or regional procurement, procurement through inter-organisational collaboration, and autonomous procurement. Finally, Subsection 4.3.3 synthesises these insights by outlining category-specific implications for procurement model redesign, providing a structured link between empirical results and the development of redesign guidelines discussed in the Chapter 5.

4.3.1 Product categories

The comparative analysis across product categories reveals both significant commonalities and category-specific characteristics in the integration of environmental sustainability within healthcare procurement. As anticipated by the findings of Round 1, consumables were analysed together with medical devices in Round 2, in line with the CPV classification, and considering

their relatively limited impact on the overall healthcare expenditure, as emerged from interviews.

4.3.1.1 Practices consistent across product categories

Reduction of transport-related emissions and reduction of packaging were among the highest-ranked practices in both product categories (means ranging from 4.72 to 4.47), indicating a strong consensus on the importance of logistic-related environmental improvements. These practices address environmental impacts occurring along the supply chain and are largely independent of product-specific characteristics. Similarly, the application of Minimum Environmental Criteria in tendering procedures was considered important for both product categories (means of 4.56 and 4.29), confirming the central role of regulatory instruments in promoting environmental sustainability through public procurement.

Other practices showing consistent relevance include procurement of recyclable containers, logistics optimisation through centralisation and aggregation, and environmental assessment of suppliers and products, all of which achieved consensus and relatively high mean scores in both categories. These practices mainly concern procurement procedures and supply chain management rather than product design, which may explain their applicability across different product types.

Overall, practices consistent across product categories mainly correspond to sustainable supply-chain improvements, while circular practices tend to be more product-specific, particularly in the case of medical devices

4.3.1.2 Practices specific to one product category

For medical devices, the integration of reusable medical devices represents a distinctive circular practice that does not have a direct equivalent in pharmaceutical procurement. Although this practice did not reach consensus and showed an IQR of 2, its inclusion highlights the potential for circular strategies based on product reuse. Conversely, for pharmaceuticals the elimination of paper package leaflets through digital solutions emerged as a category-specific practice. This practice reflects the regulatory and information requirements associated with pharmaceuticals, where package leaflets are mandatory and represent a significant source of paper consumption.

4.3.1.3 Practices showing different level of importance across product categories

The most notable difference concerns the integration of end-of-life costs into procurement decisions, which received a substantially higher mean score for medical devices (4.28) than for pharmaceuticals (3.53). This difference likely reflects the greater relevance of disposal processes for medical devices, which often involve specialised waste treatment, whereas pharmaceutical disposal costs may be less visible at the procurement stage. Smaller differences can also be observed for the environmental assessment of suppliers and products, which appears slightly more important for medical devices (4.28 vs 4.00), possibly due to the greater variability in materials and production processes associated with devices.

4.3.1.4 Limiting factors consistent across product categories

Economic barriers represent the most consistent and highly rated constraints in both medical device and pharmaceutical procurement. In particular, cost-driven procurement priorities emerged as one of the most critical barriers with mean values of 4.33 for medical devices and 4.53 for pharmaceuticals. Similarly, the higher cost of sustainable products and budget constraints were identified as major obstacles in both categories, reflecting the financial pressures faced by healthcare organisations. Low base prices in tenders were also perceived as a significant limitation, as they reduce the competitiveness of sustainable suppliers and discourage the adoption of environmentally preferable solutions. In addition to economic constraints, several tender-related barriers, such as the absence of sustainability-related quality criteria in tender specifications, the limited influence of sustainability requirements in award decisions, the lack of binding sustainability-related regulations, and the lack of standardisation in sustainable procurement practices were consistently identified across both product categories. Together, these factors indicate that sustainability is not yet fully embedded into procurement procedures and evaluation mechanisms.

Organisational and capability-related barriers also emerged as common constraints. Insufficient sustainability-related competencies, the lack of a life-cycle perspective in procurement decisions, supply-driven market orientation, and limited decision-making autonomy in centralised tenders were all identified as relevant limitations in both product categories, suggesting that organisational capabilities and governance structures play a key role in enabling or constraining the integration of sustainability into procurement decisions.

4.3.1.5 Barriers specific to one product category

Barriers related to the adoption of reusable devices were identified exclusively for medical devices. These include legal liability associated with the sterilisation of reusable devices (4.17), clinicians' preference for single-use devices (4.06), and the operational complexity involved in managing reusable devices and sterilization pathways (4.06). These constraints reflect the clinical and operational characteristics of medical devices, where patient safety considerations and logistical requirements play a central role in procurement decisions. Conversely, no barriers emerged as clearly specific to pharmaceuticals procurement, since most limiting factors affecting pharmaceuticals were also identified for medical devices, suggesting that pharmaceutical procurement is mainly influenced by systemic constraints rather than product-specific factors.

4.3.1.6 Barriers showing different levels of importance across product categories

Cost-driven procurement priorities were identified as the most critical barrier for pharmaceuticals procurement, receiving the highest mean score (4.53) among all limiting factors. This suggests that pharmaceutical procurement decisions may be particularly influenced by price competition and cost-containment objectives. Conversely, some economic and organisational barriers appear slightly more relevant for medical devices procurement. In particular, low base prices in tenders and budget constraints received higher scores for medical devices, respectively 4.50 and 4.44, indicating that financial limitations may be perceived as particularly restrictive in this category.

Finally, cultural and organisational barriers such as resistance to change and the lack of a sustainability culture were rated slightly higher for medical devices (both 3.67) than for pharmaceuticals (3.41 and 3.53). Although these differences are moderate, they suggest that the adoption of sustainable practices in medical devices procurement may be more strongly influenced by organisational attitudes and professional practices.

4.3.2 Procurement models

The comparative analysis across procurement models shows a high degree of consistency in the perceived importance of sustainability-oriented redesign elements, alongside moderate differences in their relative importance across centralised, collaborative, and autonomous procurement models. Across all procurement models, mean values consistently exceeded 4.0 and

consensus was achieved for all items, indicating a shared recognition among experts of the need to integrate sustainability more systematically into procurement processes.

Promotion of a sustainability-oriented culture emerged as the highest-ranked redesign element across all procurement models, with mean values of 4.58 for centralised procurement, 4.53 for collaborative procurement, and 4.42 for autonomous procurement. Similarly, the definition of sustainability criteria in tender specifications and the integration of technical and sustainability-related competencies consistently ranked among the most important redesign elements in all procurement models, suggesting that sustainability integration requires both clearer procedural frameworks and stronger multidisciplinary expertise. Conversely, the allocation of sustainability-related scores and the separation of environmental sustainability criteria from traditional quality criteria received slightly lower mean values across all procurement models, although still exceeding the relevance threshold. This result suggests that while experts recognise the importance of strengthening the formal weight of sustainability in tender evaluation systems, organisational and cultural changes are perceived as more fundamental enabling conditions for sustainability-oriented procurement.

However, the analysis of Kendall's W coefficients reveals limited concordance in the relative prioritisation of redesign actions within each procurement model: for both centralised and autonomous procurement, Kendall's W values indicated absent or negligible concordance, suggesting that while experts agree on what needs to be redesigned, they diverge in terms of which actions should be prioritised first. By contrast, procurement through inter-organisational collaboration showed a slightly higher, yet still weak, level of concordance, reflecting the heterogeneous institutional settings and coordination mechanisms characterising collaborative procurement arrangements.

In summary, sustainability-oriented redesign is perceived as broadly necessary, regardless of the procurement model, but context-specific factors, organisational maturity, and local constraints strongly influence how experts prioritise individual interventions, confirming that the procurement structure shapes implementation pathways more than sustainability priorities themselves.

4.3.3 Category-specific implications for procurement model redesign

While Subsections 4.3.1 and 4.3.2 examined similarities and differences separately across product categories and procurement models, this Subsection integrates these dimensions to clarify

how sustainability-oriented redesign priorities vary depending on the characteristics of the procured products and the governance structure through which procurement is conducted.

Centralised procurement models benefit from scale and coordination potential, but face limitations in terms of flexibility and responsiveness to local sustainability priorities. By contrast, autonomous procurement models allow greater adaptability to local needs but appear more sensitive to internal resource constraints and variations in sustainability-related competences. Lastly, collaborative procurement arrangements show slightly higher alignment in redesign priorities, reflecting the need for coordination and shared governance mechanisms while still exhibiting heterogeneity due to differing institutional contexts.

For medical devices and consumables, mainly procured through national or regional centralised or collaborative procurement models, experts consistently attributed high relevance to the definition of clear environmental sustainability criteria, the assignment of explicit scores to sustainability-related aspects, and the integration of technical and environmental competencies within procurement decision-making bodies. In these product categories, both sustainable practices, such as supplier environmental assessment and logistics optimisation, and circular practices, particularly the adoption of reusable devices, emerged as feasible areas for procurement intervention. At the same time, the weak or absent concordance observed in Kendall's W values indicates that, although these redesign elements are broadly recognised as important, their prioritisation is strongly influenced by contextual factors such as organizational capabilities, procurement scale, and regulatory environment. In particular, issues related to the management of reusable devices, sterilisation processes, and associated legal responsibilities suggest that redesign efforts for medical devices and consumables are closely intertwined with operational and risk-management considerations.

In the case of pharmaceuticals, mainly procured through national or regional centralised or autonomous procurement models, the implications for procurement model redesign appear more strongly shaped by regulatory constraints and intrinsic product characteristics, thereby narrowing the scope for intervention. Sustainable practices, particularly those related to logistic optimization, packaging reduction, and supplier environmental assessment were consistently recognised as relevant and feasible, whereas circular interventions or actions requiring changes to product characteristics, regulatory compliance, or end-of-life management were perceived as more constrained, suggesting that, for pharmaceuticals, procurement model redesign is more

dependent on external regulatory frameworks and market-level conditions than on internal organisational choices alone.

Therefore, the empirical evidence suggests that redesign priorities and feasible interventions must jointly consider product-specific characteristics and procurement governance structures when interpreting sustainability-related procurement outcomes. These findings provide a structured empirical basis for the development of category-sensitive procurement redesign guidelines, which are further discussed in Chapter 5.

5. Discussion

The purpose of this chapter is to discuss the results of the Delphi study in light of the research objectives and the existing literature on sustainable healthcare procurement, moving beyond the description of results to examine their underlying meaning (Subsection 5.1), implications (Subsection 5.2), and contribution to both academic research (Subsection 5.3) and procurement practice (Subsection 5.4).

5.1 Interpretation of Delphi results

This section mainly addresses the first two research objectives by interpreting the motivations, practices and barriers associated with sustainable healthcare procurement and the limitations of current procurement models.

The Delphi results provide a clear picture of how environmental sustainability is currently understood, prioritised, and operationalised within Italian healthcare procurement, highlighting both areas of strong expert convergence and dimensions characterised by persistent divergence. Overall, the findings suggest that sustainability is increasingly recognised as a relevant component of procurement decision-making across healthcare systems, in line with the existing literature on sustainable and green public procurement in healthcare contexts (Walker and Brammer, 2009; Ahsan and Rahman, 2017). However, the results also indicate that sustainability considerations are not yet fully structurally embedded or institutionalised within procurement processes, with significant variation across organisations.

A first, clear pattern emerging from the analysis concerns the convergence observed with respect to motivations for integrating environmental sustainability into healthcare procurement: motivations related to environmental impact reduction, cost containment over the product life cycle, and reputational and institutional responsibility achieved high median values and narrow interquartile ranges. This aligns with existing studies highlighting the duality between environmental consideration and cost containment characterising sustainable procurement initiatives in healthcare, where cost efficiency, risk mitigation, and environmental responsibility are increasingly interlinked rather than being perceived as conflicting objectives (Pinzone, Lettieri and Masella, 2015; Lavoie et al., 2024).

By contrast, greater heterogeneity emerges when considering the applicability and prioritisation of green and circular practices, confirming observations from prior research that the translation of sustainability objectives into concrete procurement actions remains highly context-dependent (Testa et al., 2016). For medical devices and consumables, experts agreed on practices related to the supplier environmental assessment, the inclusion of sustainability criteria in tender evaluation, and logistics optimisation. These practices are well documented in the literature as relatively mature and implementable within sustainable procurement healthcare, as they require limited changes to clinical routines (Duque-Urbe, Sarache and Gutiérrez, 2019). However, practices involving the adoption of reusable devices or circular product solutions generated more divergent evaluations, reflecting long-standing tensions between environmental benefits and concerns related to patient safety, sterilisation processes, legal responsibilities, and regulatory compliance (McGain et al., 2017; Hoveling et al., 2024). The Delphi results therefore reinforce the idea that circularity-oriented practices in healthcare procurement are not solely technical choices, but are deeply embedded in organisational risk management, regulatory frameworks, and clinical governance and operations. Moreover, for pharmaceuticals, while experts recognised the relevance of practices such as logistics optimisation and packaging reduction, other interventions, particularly those affecting product characteristics or end-of-life management, were perceived as significantly more constrained due to the intrinsic product characteristics and strict regulatory requirements. This finding is consistent with prior studies emphasising the limited discretionary power of procuring organisations in pharmaceutical supply chains, which are heavily regulated and characterised by high levels of standardisation (Guiu Segura, 2025). As such, sustainability-oriented procurement in pharmaceuticals appears more dependent on external regulatory evolution and upstream industry practices than on procurement model innovation alone.

A similar pattern of partial convergence and divergence is observed with respect to limiting factors. Economic constraints, and organisational and cultural barriers were consistently identified across product categories, coherently with the extensive evidence in the literature on the structural and capability-related challenges faced by public healthcare organisations (Zaidi et al., 2021). However, regulatory constraints emerged as particularly salient for medical devices, especially in relation to reuse, remanufacturing, and lifecycle accountability, echoing concerns raised in studies on medical device regulation and post-market responsibilities (Callea et al., 2017).

Importantly, the analysis of Kendall's W coefficients provides additional insights into the nature of expert agreement, since the generally low level of concordance in ranking suggests that experts agree more on what matters than on what should be prioritised first. This distinction, already discussed in methodological literature on Delphi studies (von der Gracht, 2012; Diamond et al., 2014), is particularly relevant in complex decision-making contexts such as healthcare procurement, highlighting the need for a multidimensional understanding of sustainability, in which prioritisation is shaped by organisational maturity, governance structures, and local contextual conditions rather than by universally agreed hierarchies.

5.2 Procurement model redesign guidelines

This Section addresses the third research objective by proposing guidelines for redesigning procurement models to better support environmental sustainability goals. Effective sustainability-oriented redesign requires adaptive guidelines that are sensitive to both the nature of the procured products and the degree of autonomy, coordination, and decision-making centralisation characterising different procurement models. Accordingly, the proposed guidelines are articulated separately for medical devices and consumables (Subsection 5.2.1), and pharmaceuticals (Subsection 5.2.2), and are intended to support a rethinking of healthcare procurement models by bridging the gap between abstract sustainability ambitions and practical constraints faced by healthcare procurement organisations.

5.2.1 Medical devices and consumables

For medical devices and consumables, sustainability-oriented redesign can be directly influenced by the procuring organisation, since experts consistently highlighted that the adoption of environmental criteria in supplier selection and in tender evaluation are both feasible and impactful, given their relatively standardised usage patterns across facilities and the predictable procurement cycles for replacement of certain equipment.

These opportunities emerge at different stages of the procurement cycle. In particular, sustainability considerations can be integrated during needs identification and planning through the evaluation of reusable alternatives and demand rationalisation, while the specification development and supplier selection phases represent the most effective leverage points for introducing environmental criteria and circular requirement in procurement decisions.

Within this context, by consolidating procurement decisions across multiple facilities, centralised procurement models should enable the standardisation of environmental assessments, and the achievement of economies of scale in areas such as packaging reduction, transport efficiency, and lifecycle impact assessment, allowing the environmental footprint to be evaluated and mitigated more efficiently across large volumes of products, thereby helping to translate sustainability objectives into tangible procurement practices while maintaining operational efficiency. In particular, centralised procurement bodies are well positioned to define standardised environmental requirements during the specification development phase and to ensure their consistent application during supplier evaluation and contracting phases.

Complementarily, collaborative procurement provides a platform for experimentation, knowledge sharing, and risk mitigation. Hospitals and healthcare organisations that engage in collaborative approaches could not only pool resources to trial reusable or circular solutions, share lessons on regulatory compliance and sterilisation practices, and coordinate efforts to engage suppliers in sustainable innovation, but also reduce organisational resistance to change and accelerate the adoption of innovative sustainable practices across the network. Collaborative arrangements are particularly valuable during the market analysis and implementation phases, where joint supplier engagement and shared operational experience can reduce uncertainty associated with innovative or reusable solutions. This inter-organisational learning could be particularly valuable for practices that involve higher perceived risks, such as reusable surgical instruments and circular product solutions, where clinical safety, legal responsibility, and regulatory oversight must be carefully managed.

However, practices involving product reuse, remanufacturing, or circular solutions encounter greater divergence in expert opinion, reflecting ongoing concerns related to patient safety, sterilisation protocols, and compliance with medical device regulations. Therefore, procurement redesign should balance ambition with pragmatism, encouraging incremental adoption of circular practices while leveraging centralised and collaborative procurement models to ensure feasibility, regulatory alignment, and organisational readiness.

5.2.2 Pharmaceuticals

For pharmaceuticals, sustainability-oriented procurement model redesign is more constrained compared to medical devices and consumables, largely due to intrinsic characteristics of the products, strict regulatory environments, and the high degree of standardisation in production

and distribution. This limits the scope for procurement-led innovation, particularly for product formulation, repackaging, or end-of-life management.

As a result, sustainability integration tends to concentrate in specific phases of the procurement cycle, particularly during specification development, supplier selection and delivery planning, where packaging and logistics-related interventions can be most effectively implemented.

Centralised procurement models should enhance sustainability by leveraging aggregated purchasing power to implement standardised environmental criteria across multiple facilities, optimise logistics and packaging, and achieve measurable reductions in environmental impact. They can also facilitate knowledge sharing among organisations on best practices and, where possible, advocate for regulatory updates and harmonisation to overcome major barriers. These interventions are mainly implemented during the specification development and contracting phases, where standardised environmental criteria and logistics requirements can be defined across multiple healthcare organisations. Conversely, autonomous procurement could allow individual healthcare organisations to adapt sustainability practices to their specific operational constraints, focusing on interventions that are feasible within existing regulatory and organisational limits.

Despite these opportunities, there remains divergence in expert opinions on the feasibility of more transformative practices, such as the use of more sustainable products in pharmaceutical formulation or bulk procurement, reflecting regulatory rigidity, the need to maintain strict quality and safety standards, and limited decision-making autonomy of healthcare buyers. Therefore, sustainability-oriented procurement redesign for pharmaceuticals should adopt an incremental approach, focusing on feasible interventions that can be implemented through centralised or autonomous mechanisms, while monitoring regulatory developments and industry innovations to identify future opportunities for broader impact. In practice, this implies prioritising interventions that can be integrated into existing procurement procedures, particularly in the planning, specification development, and delivery phases, where procurement organisations retain some degree of operational flexibility.

Figure 12 summarises the most relevant sustainability-oriented interventions for each combination of healthcare product category and procurement model.

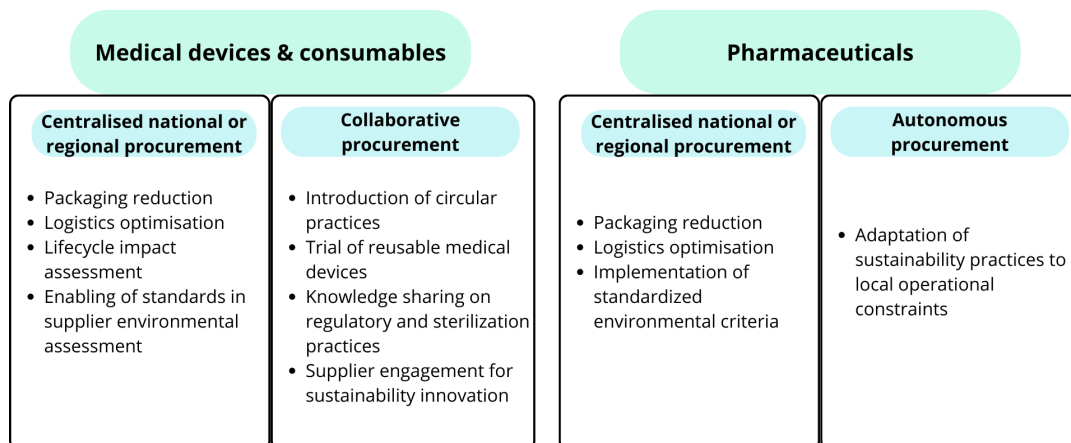


Figure 12 - Sustainability-oriented interventions by healthcare product category and procurement model

5.3 Academic implications

While previous studies have largely emphasised the importance of integrating environmental criteria into healthcare procurement, the findings of this research indicate that sustainability is no longer perceived as a secondary objective but as an increasingly embedded dimension of procurement strategy across healthcare systems. Three main academic implications emerge from the analysis, addressing both theoretical understanding and methodological approaches in sustainable healthcare procurement research:

- The results reveal strong convergence among experts regarding the motivations driving the integration of environmental sustainability, which appear largely systemic and consistent across product categories. At the same time, the study shows that the applicability and prioritisation of sustainable and circular practices remain highly context-dependent, shaped by organisational, regulatory, and operational conditions. This finding contributes to the literature by moving beyond simplified or linear interpretations of sustainable procurement, highlighting instead the coexistence of shared strategic drivers and locally contingent implementation pathways.
- Unlike much of the existing literature, which tends to examine sustainable procurement in aggregate terms, this study demonstrates that sustainability-related priorities and feasible interventions vary significantly depending on both the characteristics of the procured products and the configuration of procurement models, which jointly influence sustainability outcomes. Therefore, the research advances a more differentiated and context-sensitive conceptualisation of sustainable healthcare procurement.

- Finally, the study contributes methodologically by illustrating the value of combining qualitative exploration and quantitative prioritisation within a Delphi framework. In particular, the use of Kendall's W coefficient provides additional insight into the nature of expert agreement, showing that consensus tends to emerge more strongly on the relevance of sustainability dimensions than on their relative prioritisation. This distinction is especially relevant in complex decision-making environments such as healthcare procurement, where multiple objectives and constraints coexist, and contributes to the methodological discussion on the interpretation of consensus in Delphi-based research.

5.4 Practical implications for healthcare organisations

The findings of this study provide several practical insights for healthcare organisations seeking to integrate environmental sustainability into procurement practices in a structured and operationally feasible way. In particular, sustainability-oriented procurement requires a combination of strategic alignment, organisational capability, and context-sensitive implementation, with procurement models acting as enabling mechanisms rather than isolated solutions.

First, healthcare organisations should move beyond symbolic initiatives and progressively institutionalise sustainability as a core procurement objective, integrating environmental criteria into supplier selection and tender evaluation, developing internal competences related to lifecycle thinking and environmental assessment, and strengthening coordination between procurement, clinical, and sustainability functions.

Moreover, procurement models should represent levers for sustainability implementation: centralised procurement can support the standardisation of environmental criteria during the requirement specification phase, enable the consolidation of demand, and the achievement of measurable environmental improvements through economies of scale, particularly for medical devices and consumables where procurement organisations retain greater influence over suppliers and product specifications. Collaborative procurement models can facilitate experimentation and knowledge sharing, allowing healthcare organisations to jointly test circular practices, engage suppliers in sustainability innovation, and mitigate risks associated with regulatory compliance and clinical safety; finally, where regulatory constraints and market standardisation limit procurement discretion, as in pharmaceutical procurement, more autonomous and locally adaptive approaches may enable organisations to implement feasible sustainability actions within existing operational boundaries.

Lastly, the study confirms that economic pressures, regulatory requirements, and organisational readiness significantly shape the feasibility of sustainability initiatives. Healthcare organisations should therefore adopt an incremental approach, focusing initially on high-impact and operationally feasible interventions, such as assessing the suppliers' environmental performance during the evaluation and selection phase, logistics optimisation, and the progressive inclusion of lifecycle considerations in procurement decisions. Conversely, for practices involving higher levels of uncertainty or risk, particularly circular solutions for medical devices and more transformative interventions in pharmaceuticals, implementation should be supported by continuous monitoring of regulatory developments and active engagement with suppliers and industry stakeholders to anticipate future opportunities for broader sustainability integration. The operational implications discussed can be mapped onto the main phases of the procurement cycle, highlighting where sustainability-oriented interventions can be most effectively integrated for different healthcare product categories. Figure provides a structured overview of how the proposed guidelines can be embedded across procurement phases for medical devices and consumables and for pharmaceuticals.

Overall, the findings suggest that advancing environmental sustainability in healthcare procurement is less about adopting a single procurement configuration and more about developing adaptive, coordinated, and context-aware procurement strategies, which can allow healthcare organisations to progressively translate sustainability objectives into operational procurement practices while maintaining clinical, regulatory, and economic viability.

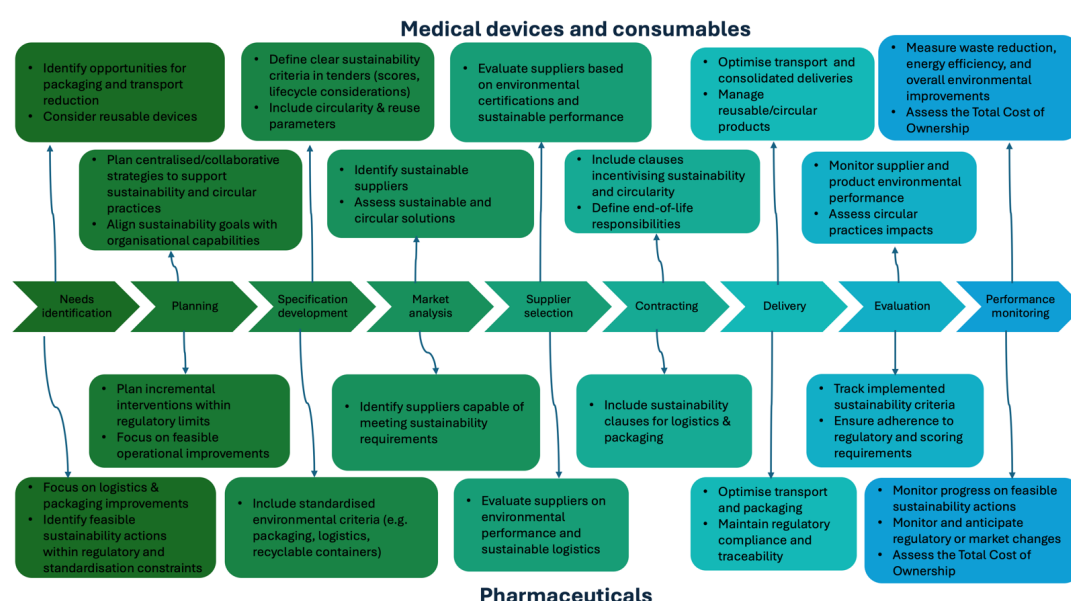


Figure 13 - Sustainability-oriented procurement guidelines mapped onto the procurement cycle for medical devices and consumables and for pharmaceuticals

6. Conclusions

The aim of this thesis was to examine how healthcare procurement models can be redesigned to better align with environmental sustainability objectives across different healthcare product categories. By combining qualitative and quantitative evidence collected through a Delphi study, the findings contribute to a more differentiated, empirically grounded, and context-sensitive understanding of sustainable healthcare procurement, highlighting the role of product characteristics and procurement structures in shaping feasible sustainability pathways. This chapter concludes the thesis by summarising the key findings (Section 6.1), discussing the main limitations of the study (Section 6.2), and outlining directions for future research (Section 6.3).

6.1 Summary of key findings

The findings of this thesis provide a nuanced understanding of how healthcare procurement models can be redesigned to better align with environmental sustainability objectives across different product categories. Three main insights can be highlighted:

- Sustainability is an increasingly embedded dimension of healthcare procurement. Experts consistently recognised that integrating environmental considerations is no longer peripheral but a core objective influencing decision-making across healthcare systems. This applies to all product categories, highlighting the systemic relevance of sustainability motivations within procurement processes, particularly in strategy definition and policy-setting phases
- Product characteristics and procurement models jointly shape feasible sustainability interventions. For medical devices and consumables, where usage patterns are relatively standardised and procurement cycles predictable, centralised or collaborative procurement models call for organisations to implement sustainable practices such as supplier environmental assessment, logistics optimisation, and packaging reduction, which primarily influence the supplier selection and execution phases. In addition, circular practices, including the adoption of reusable or refurbished devices, require careful redesign, taking into account end-of-life management and risk governance. By contrast, for pharmaceuticals, the high degree of standardisation, strict regulatory constraints, and limited procurement discretion substantially restrict the scope for transformative interventions, making more ambitious sustainability interventions largely contingent on regulatory

evolution and upstream industry practices rather than on procurement model innovation alone.

- Sustainability-oriented redesign requires context-sensitive and adaptive approaches. The Delphi results indicate that expert consensus is stronger regarding the relevance of sustainability dimensions than their relative prioritisation, suggesting that procurement redesign cannot follow a uniform pathway but should be shaped by organisational maturity, regulatory environments, and product-specific operational characteristics. Consequently, implementing these guidelines involves incremental adoption, starting with high-impact, operationally feasible practices, and gradually expanding toward more complex or innovative initiatives, affecting procurement steps such as strategy definition, supplier selection, execution, and end-of-life management.

Overall, the study demonstrates that effective integration of environmental sustainability into healthcare procurement requires a coordinated, context-aware, and category-specific approach in which product characteristics, procurement models, and organisational capabilities determine the feasible scope and sequencing of sustainability interventions across the procurement process. In doing so, this research addresses a gap in the existing literature, which has often treated sustainable healthcare procurement as a relatively uniform or aggregate phenomenon, by showing that adaptive and context-sensitive procurement strategies are essential for translating sustainability objectives into operational practices while preserving clinical, regulatory, and economic viability, rather than identifying a single optimal procurement configuration.

6.2 Limitations

This study presents several limitations that should be acknowledged when interpreting the findings.

First, methodological limitations related to the Delphi approach may affect the validity of the results. With regard to external validity, the generalisability of the findings may be limited, as the study relies on a specific panel of experts whose perspectives may not fully represent those of the broader population of healthcare procurement professionals. Moreover, all experts involved were based in Italy, an advanced economy with a well-developed healthcare system characterised by strong regulatory frameworks and institutional constraints. As a result, the applicability of the findings to other healthcare systems may be limited.

At the same time, internal validity may be influenced by several factors inherent to Delphi studies. In particular, results remain contingent on the selection and composition of the expert panel, including the number of participants, their level of expertise, and the diversity of their backgrounds. Different expert groups, or the same group at different points in time, may produce different outcomes, especially in rapidly evolving and highly regulated contexts such as healthcare. Furthermore, questionnaire design and feedback mechanisms may introduce bias if questions are interpreted differently by participants or if feedback influences subsequent responses. In addition, expert judgements are inherently subjective and may be affected by personal bias or conformity dynamics, where panellists adjust their responses to align with perceived group tendencies. Finally, the analysis of open-ended responses in the exploratory phase involves interpretative judgement by the researchers, potentially introducing coding or aggregation bias.

An additional methodological limitation is that the Round 2 results were not returned to the experts, preventing them from reviewing and potentially adjusting their judgements based on the group responses, which could have influenced consensus and prioritisation outcomes.

Second, the findings should be interpreted in light of the dynamic nature of sustainability and healthcare procurement. Sustainability priorities and procurement practices may evolve over time due to regulatory changes, technological innovation, or shifts in organisational maturity, potentially affecting the long-term transferability of results.

Third, the scope of the study focuses primarily on environmental sustainability, without fully addressing the broader social and economic dimensions of sustainable procurement. While this focus was intentional and aligned with the research objectives, it limits the ability to capture potential trade-offs or synergies between environmental, social, and economic sustainability goals.

Finally, although the study identifies procurement redesign guidelines, it does not empirically test their implementation or measure their real-world impact. As such, the proposed redesign elements should be interpreted as conceptually grounded and expert-informed rather than as fully validated operational models.

6.3 Future research directions

This study opens several avenues for future research, both in terms of theoretical development and empirical investigation.

First, future studies could empirically test the implementation and impact of sustainability-oriented procurement redesign models within real healthcare settings. While the research provides expert-informed guidelines, further work is needed to assess how these redesign elements perform in practice, particularly in relation to environmental outcomes, cost implications, and organisational feasibility across different healthcare systems.

Second, further research could expand the scope of sustainable healthcare procurement beyond environmental sustainability, incorporating social and economic dimensions. Exploring potential trade-offs and synergies between environmental performance, cost containment, supply resilience, and social responsibility would contribute to a more comprehensive understanding of sustainability in healthcare procurement.

Third, given the dynamic and highly regulated nature of healthcare procurement, longitudinal and comparative studies could examine how sustainability priorities, procurement models, and regulatory frameworks evolve over time. Such research would help clarify whether the patterns identified in this study remain stable or change in response to technological innovation, policy developments, or shifts in organisational maturity.

Fourth, future work could adopt more granular perspectives, investigating sustainability practices at the supplier level, inter-organisational coordination mechanisms, and category-specific dynamics, particularly for pharmaceuticals, where procurement influence is more constrained and sustainability outcomes depend strongly on upstream actors. Expanding the range of stakeholders involved, including clinicians, policymakers, and industry representatives, could further enrich the understanding of feasibility, regulatory constraints, and supply-chain dynamics of sustainability-oriented procurement.

In addition, this study also suggests some methodological extensions. Future research could strengthen robustness by conducting additional Delphi rounds focusing on items that did not reach consensus, and performing stability tests (e.g., Spearman's ρ) to assess the consistency of expert responses across rounds. Moreover, further studies could re-examine items emerging

from the exploratory phase that were not retained in Round 2, potentially uncovering overlooked sustainability dimensions or emerging themes.

Overall, these directions highlight the need for continued research combining methodological rigour, empirical validation, and context-sensitive analysis to advance the understanding and practical implementation of sustainable healthcare procurement.

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Appendix 1 – Round 1 material

A1.1 Glossary of terms

Procurement model: A procurement model refers to the set of practices that govern how an organization plans, manages, and executes its procurement activities. It includes the processes, roles, decision-making criteria, sourcing strategies, and supplier relationships involved in acquiring goods and services (Source: Dimitri, Piga and Spagnolo, 2006).

Environmental sustainability goals: Environmental sustainability goals refer to the objectives set by organizations, sectors, or policymakers aimed at reducing negative environmental impacts and promoting the responsible use of natural resources. These goals typically focus on areas such as reducing greenhouse gas emissions, minimizing waste and pollution, improving energy and resource efficiency, enhancing product circularity, and protecting ecosystems (Source: <https://sdgs.un.org/goals>. Accessed: 25th of August 2025).

Medical devices: A medical device is any instrument, apparatus, appliance, implant, reagent, material or other article intended by the manufacturer to be used, alone or in combination, for human beings for one or more of the following specific medical purposes: diagnosis, prevention, monitoring, treatment or alleviation of disease, alleviation of or compensation for an injury or handicap, investigation, replacement or modification of the anatomy or of a physiological process, or control of conception, and which does not primarily achieve its principal intended action by pharmacological, immunological or metabolic means. The reference classification codes, taken from “Linee guida del modello CE” and the “Common Procurement Vocabulary”, and used to determine which products are considered, include the following product categories: Medical devices; Implantable medical devices; In vitro diagnostic medical devices (IVD) (Source: <https://www.who.int/teams/health-product-policy-and-standards/assistive-and-medical-technology/medical-devices>. Accessed: 25th of August 2025).

Pharmaceuticals: A medicinal product is a substance or combination of substances that is intended to treat, prevent or diagnose a disease, or to restore, correct or modify physiological functions by exerting a pharmacological, immunological or metabolic action. The reference classification codes, taken from “Linee guida del modello CE” and the “Common Procurement Vocabulary”, and used to determine which products are considered, include the following product categories: Medicines with marketing authorization excluding vaccines and regionally produced blood-derived products; Medicines without marketing authorization; Regionally produced blood-derived products; Blood and blood components; Prophylactic materials

(vaccines); Veterinary materials and products (Source: <https://www.ema.europa.eu/en/glossary-terms/medicinal-product>. Accessed: 25th of August 2025).

Consumables: A consumable is a supply item, sometimes required for the use of medical equipment, that is essential for the performance of diagnostic, therapeutic, monitoring, or hygiene-related procedures. No reuse or limited reuse is allowed for consumables. Consumables must be regularly replenished to ensure continuity of patient care and clinical operations. The reference classification codes, taken from “Linee guida del modello CE” and the “Common Procurement Vocabulary”, and used to determine which products are considered, include the following product categories: Diagnostic supplies; Radiodiagnostic supplies; Disposal non-chemical medical consumables; Haematological consumables; Surgical supplies; Other non-therapeutic goods and products; Wardrobe, cleaning, and general facility supplies; Fuels, petroleum products, and lubricants; IT supplies and stationery; Maintenance supplies (Source: https://iris.who.int/bitstream/handle/10665/44407/9789241564045_eng.pdf. Accessed: 25th of August 2025).

Barriers: A barrier is an organizational, regulatory, economic, technical, or cultural obstacle that hinders or slows down the adoption of environmentally sustainable procurement models in the healthcare sector (Source: European Commission, 2016).

Practices: A practice is an action or operational process adopted by healthcare organizations to integrate environmental sustainability into procurement activities (Source: <https://europe.noharm.org/media/300/download?inline=1>. Accessed: 25th of August 2025).

A1.2 Round 1 Questionnaire

Respondent profile questions:

1. What is your current professional role?
2. How many years of experience do you have in your current organization?
3. How many years of experience do you have in the healthcare industry?
4. What product categories are you responsible to procure within your organization?
 - a. Medical devices
 - b. Pharmaceuticals
 - c. Consumables
 - d. I am not currently responsible for procurement

Questions on sustainable and circular procurement:

1. Please indicate which procurement model predominantly applies to each product category in your organization (maximum of 2 options per product category).

	Medical devices	Consumables	Pharmaceuticals
Autonomous procurement (through competitive tendering by individual ASL/ASO)			
Regional procurement through collaboration among multiple ASL/ASO			
Regional centralized procurement through purchasing centre			
National procurement through CONSIP/MEPA			
Direct procurement (through direct award without tender)			
Not applicable/ I don't know			

2. What motivations provide a stimulus for incorporating environmental sustainability considerations into healthcare procurement processes?

Drivers	Medical devices	Consumables	Pharmaceuticals

3. What green or circular procurement practices have you observed or implemented in the procurement of different healthcare product categories?

Green/circular practices	Medical devices	Consumables	Pharmaceuticals

4. What are the main barriers to implementing green and circular procurement practices for different healthcare product categories?

Barriers to green/circular procurement	Medical devices	Consumables	Pharmaceuticals

5. What are the main sustainability-related obstacles determined by procurement decisions in the healthcare industry?

Obstacles	Medical devices	Consumables	Pharmaceuticals

6. What limitations do the current procurement models present in achieving environmental sustainability objectives?

Limitations of current procurement models	Medical devices	Consumables	Pharmaceuticals

7. What elements of current procurement models should be redesigned to better align with environmental sustainability goals?

Procurement model elements to be redesigned	Medical devices	Consumables	Pharmaceuticals

Appendix 2 – Round 2 material

A2.1 Round 2 invitation e-mail sent to Delphi study participants

“Dear ...,

Together with the research team at the Politecnico di Torino, we would like to sincerely thank you once again for your valuable contribution to Round 1 of the Delphi study on environmental sustainability in healthcare procurement models.

Your insights and responses were essential in shaping the structure and content of Round 2 of the study. Building on the comments collected from all participants during Round 1, this second round aims to assess the relevance of the identified items and to evaluate the level of consensus among participants.

As mentioned during the interview, we now kindly invite you to complete the Round 2 questionnaire, available at the following link: <https://form.jotform.com/253364064354052>.

The estimated completion time is approximately 15-20 minutes. The deadline for completion is the 9th of January.

Your participation is essential to support the development of guidelines for more sustainable healthcare procurement practices.

Should you require any further information or clarification, please do not hesitate to contact us. We thank you in advance for your valuable support.

Kind regards.”

A2.2 Round 2 Questionnaire

Instructions for completion:

For each proposed item, based on your experience, please indicate the level of importance using a 5-point Likert scale, where: 1 = “Not important at all”; 2 = “Slightly important”; 3 = “Neutral”; 4 = “Important”; 5 = “Very important”. If you are not involved with a specific product category, do not use a particular procurement model, or consider the item not applicable to the product category, please select the option “I don’t know/Non applicable”. Next to each item,

you will also find a dedicated space where you may, if you wish, add comments, clarifications, or suggestions to further elaborate on the topic. Thank you for your contribution, which is essential for the development of more sustainable healthcare procurement models.

Questions:

1. Please indicate how important you consider each of the following drivers in encouraging the integration of environmental sustainability into healthcare procurement processes.

Table A1 - Motivations to integrate environmental sustainability in healthcare procurement

Please indicate how important you consider each of the following drivers in encouraging the integration of environmental sustainability into healthcare procurement processes		
Items		Comments
Reduction of the environmental impacts of packaging: The reduction of packaging volumes and the adoption of sustainable packaging materials help decrease waste generation, reduce the need for incineration, and limit emissions associated with waste disposal.		
Presence of regulatory requirements related to sustainability: Legislation and tender specifications that include environmental criteria encourage the integration of sustainability into procurement decision-making.		
Ethical motivations: The individual environmental awareness and ethical sensitivity of decision-makers promote the integration of sustainability into procurement processes, independently of regulatory obligations.		
Awareness of the environmental impact of products: Decision-makers' awareness of the environmental impact of products, together with the organization's commitment, fosters the adoption of sustainable procurement practices.		
Sustainable management of reusable medical devices: The efficient use of reusable medical devices should ensure a balance between economic and environmental sustainability by optimizing performance, extending product lifespan, and reducing waste and costs.		
Total cost of ownership (TCO): Products should be environmentally sustainable and economically viable when considering costs across their entire life cycle.		
Reduced workload related to waste management: The management and disposal of healthcare waste require time and resources, increasing the internal workload associated with proper waste handling.		
Reduction of waste disposal costs: The procurement of sustainable or recyclable materials and more sustainable disposal practices contributes to reducing healthcare waste management costs.		
Logistics optimization: Integrating sustainability into procurement enables the optimization of storage, transportation, and warehouse space, reducing operational costs and improving supply chain efficiency.		
Waste reduction: Green and circular practices reduce waste generation, thereby improving resource efficiency and overall environmental performance.		

2. For each product category, please indicate how important you consider each of the following green or circular practices in promoting environmental sustainability in healthcare procurement.

Table A2 - Green and circular practices in healthcare procurement

For each product category, please indicate how important you consider each of the following green or circular practices in promoting environmental sustainability in healthcare procurement				
Items	Medical devices	Comments	Pharmaceuticals	Comments
Logistics optimization through centralization and aggregation: The centralization of warehouses and the aggregation of deliveries enable the rationalization of transport activities, reducing waste, costs, and energy consumption in healthcare logistics				
Reduction of transport-related emissions: The adoption of low-emission vehicles and efficient transport planning reduces fuel consumption and the environmental impact of healthcare product distribution				
Reduction of packaging: Sustainable packaging management (e.g. use of recycled or recyclable materials and reduced packaging volumes) decreases waste generation and environmental impacts along the healthcare supply chain				
Elimination of paper package leaflets for pharmaceuticals: Replacing paper package leaflets with digital solutions (e.g. QR codes) reduces paper waste and the overall environmental impact of pharmaceuticals				
Integration of end-of-life costs into purchasing decisions: The inclusion of end-of-life and disposal costs in purchasing decisions helps reduce waste and operational costs				
Application of Minimum Environmental Criteria in tendering procedures: The application of Minimum Environmental Criteria in tendering procedures ensures compliance with minimum environmental sustainability standards for procured products				
Environmental assessment of suppliers and products: Products and suppliers are selected based on compliance with environmental standards, recognized certifications, and the use of sustainable materials				
Procurement of products made from recycled materials: Purchasing products made from recycled materials (e.g. recycled paper) helps reduce environmental impacts and supports the circular economy				
Procurement of recyclable containers: The purchase of containers made from recyclable materials contributes to reducing waste volumes and improves the sustainability of materials management by facilitating proper end-of-life disposal				
Integration of reusable medical devices: Promoting the use of reusable devices (e.g. surgical instruments or operating room materials) through safe and controlled sterilization processes extends product lifecycles, reduces waste, and lowers the environmental impact of healthcare procedures				

3. For each product category, please indicate how relevant you consider each of the following factors in hindering the adoption of green and circular practices or sustainable procurement decisions in healthcare.

Table A3 - Factors hindering the adoption of green and circular practices in healthcare procurement

For each product category, please indicate how relevant you consider each of the following factors in hindering the adoption of green and circular practices or sustainable procurement decisions in healthcare				
Items	Medical devices	Comments	Pharmaceuticals	Comments
Clinicians' preference for single-use devices: Clinicians tend to prefer single-use devices for reasons related to safety, convenience, and perceived effectiveness, limiting the adoption of reusable alternatives				
Complexity in managing reusable devices: The introduction of reusable devices increases operational and logistical complexity, particularly with regard to sterilization pathways				
Legal liability related to the sterilization of reusable devices: Legal responsibility associated with the sterilization of reusable devices makes single-use solutions a simpler option from an operational perspective				
Higher cost of sustainable products: Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption				
Budget constraints: Budget limitations reduce purchasing flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints				
Cost-driven procurement priorities: Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices				
Resistance to change: Conservative mindsets and resistance to change among healthcare professionals hinder the adoption of sustainable practices				
Lack of a sustainability culture: Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement				
Insufficient sustainability-related competencies: A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes				
Sustainability not considered a priority: The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority				
Sustainability requirements not effectively evaluated in tender awards: Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions				
Sector-specific regulatory constraints: Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations				
Lack of binding sustainability-related regulations: The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects				
Lack of standardization in sustainable procurement: The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria				
Low base prices in tenders: Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers				
Supply-driven market orientation: Sustainable innovation is mainly driven by suppliers, while healthcare organizations do not always define requirements that stimulate sustainable product innovation				
Lack of a life-cycle perspective: The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions				
Limited decision-making autonomy in centralized tenders: In centralized procurement procedures, local decision-makers have limited autonomy; established criteria must accommodate the heterogeneous levels of environmental awareness and preparedness across participating organizations, limiting the adoption of more sustainable solutions				
Absence of sustainability-related quality criteria in tender specifications: Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions				

4. For each procurement model, please indicate how important you consider redesigning each of the following elements of current procurement models in order to align them with environmental sustainability objectives.

Table A4 - Redesign elements of healthcare procurement models

For each procurement model, please indicate how important you consider redesigning each of the following elements of current procurement models in order to align them with environmental sustainability objectives				
Items	Centralized procurement through a regional or national purchasing body (e.g. CONSIP/MEPA)	Regional procurement through collaboration among multiple ASL/ASO	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Comments
Definition of sustainability criteria: Sustainability requirements to be included as evaluation criteria in tender specifications should be clearly defined in order to guide procurement decisions toward more sustainable practices.				
Allocation of sustainability-related scores in tender specifications: Environmental criteria should be assigned a significant weight in tender scoring systems, effectively incentivizing suppliers to develop sustainable solutions, even if this may potentially reduce the number of eligible suppliers				
Separation of environmental sustainability criteria from quality criteria in procurement decision-making: Environmental sustainability should be considered as an autonomous evaluation criterion, rather than being embedded within quality criteria, and should be assigned an appropriate weight in the award process so as to influence procurement decisions alongside price and quality				
Integration of technical and sustainability-related competencies: Strengthening the role of clinical engineers and integrating professionals with environmental sustainability expertise within technical committees or working groups involved in tender design would promote a multidisciplinary approach capable of balancing technical efficiency and environmental objectives				
Promotion of a sustainability-oriented culture: The implementation of initiatives and training programs aimed at increasing awareness of the environmental impacts of the healthcare sector and encouraging sustainability-oriented purchasing decisions				

Appendix 3

Table A5 - Disaggregated barriers to green and circular practices

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEPA	Direct procurement (through direct award without tender)			
Barriers to green and circular practices	Clinical preferences	Clinicians' preference for single-use devices	Clinicians tend to prefer single-use devices for reasons related to safety, convenience, and perceived effectiveness, limiting the adoption of reusable alternatives	✓			✓	✓	✓	✓		A1,C1,E1,G1,G2,G3,H1,H2,L1,L2,M1,M2,J2	13	8
	Infrastructure and territory related barriers	Transport sustainability constrained by territorial characteristics	The geographical morphology and road infrastructure affect transport efficiency, making it more difficult to adopt sustainable logistics solutions and reduce emissions	✓	✓	✓			✓		✓	K1,K2	2	1
	Managerial barriers	Complexity in managing reusable devices	The introduction of reusable devices increases operational and logistical complexity, particularly with regard to sterilization pathways	✓			✓	✓	✓		✓	A1,D1,E1,H2,K1,K2,J2	7	6
		Legal liability related to the sterilization of reusable devices	Legal responsibility associated with the sterilization of reusable devices makes single-use solutions a simpler option from an operational perspective	✓				✓	✓			D1	1	1
		Limited applicability of reusable devices outside the hospital setting	Reusable devices are difficult to use by patients in home-care therapies	✓				✓	✓			E1,H2,M1,M2	4	3
		Lack of warranty and maintenance for recycled non-clinical supplies	The use of recycled materials or products not supplied by the original manufacturer may result in the absence of warranties or maintenance services, creating a barrier to the adoption of more sustainable products		✓		✓				✓	J1	1	1
		Risk of product obsolescence in Product-Service System contracts	In long-term Product-Service System contracts, technological evolution and product obsolescence make it difficult to update or renegotiate ongoing tenders, limiting the adoption of sustainable solutions	✓				✓		✓		L1,L2	2	1
		Supplier orientation towards single-use devices	Suppliers tend to promote single-use products, limiting the adoption of more sustainable reusable solutions	✓				✓	✓			J2	1	1
		Single-use devices as support to reusable devices	Single-use devices remain necessary as a backup to prevent stock-outs, reducing the possibility of a full transition to reusable solutions	✓				✓	✓			J2	1	1
		Trade-off between circular and traditional surgical kits	The choice of surgical kits involves a trade-off between sustainability, through the introduction of reusable devices after sterilisation, and practicality or standardisation	✓				✓	✓			D1	1	1
	Economic barriers	Lack of economic convenience of circular practices	The adoption of circular practices, such as device sterilisation, is limited by the lack of clear economic benefits, especially for low unit-cost products or when processes like sterilisation are outsourced	✓					✓	✓		B1,B2,E1	3	2
		Higher cost of sustainable products	Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption	✓	✓	✓	✓	✓	✓	✓		D1,E1,H1,J1	4	4
		Difficulty justifying sustainability-related costs	Additional expenses associated with sustainable practices are difficult to justify within organizational budgets, hindering their implementation	✓	✓	✓			✓		✓	K1,K2,N1,N2	4	2
		Budget constraints	Budget limitations reduce procurement flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Cost-driven procurement priorities	Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices	✓	✓	✓	✓	✓	✓	✓	✓	C2,E1,J1,K1,K2,M1,M2,N1,N2	9	6
	Cultural barriers	Resistance to change	Conservative mindsets and resistance to change among healthcare professionals hinder the adoption of sustainable practices	✓		✓		✓	✓			D1,H2,L1,L2,M1,M2,O1	7	5
		Public administration mindset not oriented toward sustainability	A conservative approach and limited environmental awareness within public administration reduce the adoption of sustainable procurement practices	✓	✓	✓	✓	✓	✓	✓		I1,O1	2	2
		Variable sustainability awareness	Sensitivity and awareness of sustainability issues vary among healthcare stakeholders, influencing the adoption of green procurement practices	✓		✓		✓	✓		✓	J1,N1,N2,O1	4	3
		Generational barriers to sustainability	The relatively high average age of healthcare personnel contributes to lower openness to innovative and sustainable practices and greater resistance to change	✓		✓						O1	1	1
		Lack of a sustainability culture	Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement	✓	✓	✓	✓	✓	✓	✓	✓	E1,H1,K1,K2,I1,L1,L2,O1	8	6
	Lack of sustainability-related competencies	Need for sustainability knowledge among clinical staff	Clinical staff also need to understand environmental aspects, as procurement decisions involve multiple actors and their awareness influences sustainability integration	✓		✓		✓	✓		✓	J1,L1,L2,M1,M2	5	3
		Insufficient sustainability-related competencies	A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes	✓	✓	✓	✓	✓	✓	✓	✓	C1,C2,H2,I1	4	3
	Regulatory barriers	Restrictions on bulk purchasing	Italian regulations prevent the purchase of pharmaceuticals without individual packaging, limiting packaging reduction and optimization of dosing and logistics			✓	✓		✓			E1,F1,H1	3	3
		Absence of mandatory sustainability requirements in tenders	The lack of mandatory sustainability requirements for certain products limits the integration of environmental criteria into procurement processes	✓	✓	✓	✓	✓	✓	✓		C1,G1,G2,G3,H1,L1,L2	7	4
		Lack of regulation on reusable devices	The absence of regulations allowing or incentivising the use of reusable devices limits the adoption of more sustainable solutions in the healthcare sector	✓			✓		✓			I1	1	1
		Regulatory constraints	Binding rules and regulations may restrict the implementation of sustainable procurement practices by preventing the introduction of more sustainable solutions	✓	✓	✓			✓		✓	K1,K2,N1,N2	4	2
		EU-Italy regulatory inconsistency on single-use devices reuse	While EU Regulation 2017/745 (MDR) – Article 17 allows reuse after reprocessing, Italian legislation (Ministry of Health note on medical devices, 1 April 2005) prohibits the reuse of single-use devices, limiting the implementation of circular practices	✓					✓			E1	1	1
	Organizational barriers	Lack of procedural benefits	Sustainable practices do not provide immediate procedural advantages (e.g. simplification of bureaucracy or procurement timelines) for procurement offices, reducing incentives for their adoption	✓	✓	✓	✓	✓	✓			A1	1	1
		Lack of strategic vision	The absence of strategies and a life-cycle perspective prevents a systematic approach to sustainability in procurement	✓	✓	✓	✓	✓	✓	✓	✓	C1,E1,G1,G2,G3,K1,K2	7	4
		Sustainability not considered a priority	The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority.	✓		✓	✓	✓	✓	✓		B1,B2	2	1
	Procedural barriers	Sustainability requirements not effectively evaluated in tender awards	Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions	✓	✓	✓	✓		✓		✓	E1,J1	2	2
		Lack of standardisation of supplier certifications	The absence of clear standards for supplier certifications makes it difficult to properly assess product sustainability	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
	Product and packaging related barriers	Sustainability constrained by pharmaceutical product characteristics	The intrinsic properties of pharmaceuticals and the constraints of their production processes make it difficult to introduce sustainability practices, such as eco-friendly materials or alternative packaging			✓	✓		✓			I1	1	1
		Limited availability of sustainable products	The limited supply of sustainable products from suppliers represents a barrier to the adoption of green procurement practices	✓	✓	✓		✓	✓			M1,M2	2	1
		Lack of eco-design in packaging	The absence of packaging eco-design, aimed at reducing plastic and paper or using more sustainable materials, limits the reduction of environmental impacts	✓				✓	✓			F1	1	1

Table A6 - Disaggregated sustainability-related obstacles in procurement decisions

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEPA	Direct procurement (through direct award without tender)			
Sustainability-related obstacles in procurement decisions	Regulatory obstacles	Sector-specific regulatory constraints	Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations	✓		✓	✓	✓	✓	✓		E1,F1,H1	3	3
		Lack of binding sustainability-related regulations	The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Short-term political vision	The lack of long-term political planning limits sustainable procurement decisions, favoring short-term solutions over long-term environmental investments	✓	✓	✓	✓	✓	✓	✓		I1	1	1
	Cultural obstacles	Lack of sustainability culture	Limited awareness and sensitivity to sustainability issues constrain the adoption of green and circular practices in procurement, especially in the absence of regulatory requirements	✓	✓	✓	✓		✓		✓	E1,H1,K1,K2,M1,M2,N1,N2	8	5
		Price-driven procurement culture	Procurement decisions prioritize price over sustainability, limiting the integration of green and circular practices	✓	✓	✓	✓		✓	✓		C2,E1	2	2
		Sustainability not considered a priority	Environmental sustainability is given limited consideration in procurement decisions due to the lack of priority, strategic planning, or defined objectives, constraining the adoption of green and circular practices	✓	✓	✓	✓		✓	✓		C2,G1,G2,G3,N1,N2	6	3
	Organizational obstacles	Lack of sustainability knowledge	Procurement managers often lack specific sustainability expertise, limiting their ability to integrate environmental criteria and assign coherent scores	✓		✓			✓			E1	1	1
		Lack of standardization in sustainable procurement	The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria	✓		✓	✓	✓	✓	✓		O1	1	1
		Limited internal bargaining power	Procurement decisions are strongly influenced by clinicians, reducing the ability of procurement departments to negotiate more sustainable solutions	✓	✓		✓	✓	✓			H2	1	1
	Economic obstacles	Economic constraints	Budget management not oriented toward sustainability, combined with higher costs of sustainable products, limits their adoption, especially in the absence of explicit regional requirements									D1,G1,G2,G3,M1,M2	6	3
		Low base prices in tenders	Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers	✓		✓	✓	✓	✓	✓		B1,B2,M1,M2	4	2
		Trade-off between social and environmental sustainability	The integration of environmental sustainability may increase costs, creating a conflict with the hospital's social objective of treating the highest possible number of patients	✓		✓			✓			E1	1	1
		Trade-off between single-use and reusable devices actual costs	The choice between single-use and reusable devices entails different impacts: single-use products increase waste generation, while reusable products generate energy and management costs that must be considered in decision-making	✓					✓		✓	K1,K2	2	1
		Budget fragmentation into silos	Procurement decisions are fragmented across budget silos, limiting the integration of sustainability and reusable solutions	✓		✓	✓	✓	✓	✓		D1,L1,L2	3	2
	Market-related obstacles	Supply-driven market orientation	Sustainable innovation is mainly driven by suppliers, while healthcare organizations do not always define requirements that stimulate sustainable product innovation	✓	✓	✓	✓	✓	✓	✓		L1,L2,M1,M2	4	2
	Procedural obstacles	Increased managerial complexity of procurement procedures	Integrating sustainability criteria into procurement increases operational and managerial complexity for those responsible for tendering and contracting	✓		✓			✓			E1	1	1
		Absence of sustainability criteria in tender specifications	Environmental sustainability criteria are absent or optional in tender documents, while technical and quality requirements prevail, reducing incentives for sustainable procurement	✓		✓	✓	✓	✓	✓		A1,B1,B2,D1,F1,L1,L2	7	5
		Sustainability assessment limited to certifications	Product sustainability is assessed solely based on certifications, without considering full life-cycle environmental impacts	✓	✓	✓	✓	✓	✓	✓	✓	J1,M1,M2	3	2
		Lack of a life-cycle perspective	The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Difficulty in quantifying sustainability performance	Objectively measuring sustainability impacts within tender award decisions remains complex and challenging	✓	✓		✓	✓	✓			A1	1	1
		Limited recognition of sustainable suppliers	Manufacturers adopting sustainable practices receive limited benefits in centralized tenders, often gaining only reputational advantages without affecting contract awards	✓	✓	✓	✓	✓	✓			A1	1	1
		Limited availability of sustainable suppliers	The small number of companies adopting sustainable practices restricts procurement options and limits the integration of sustainability into procurement processes	✓	✓	✓	✓	✓	✓	✓		I1	1	1
		Lack of incentives for innovation	The absence of incentives or reward mechanisms reduces the attractiveness of introducing innovative and sustainable requirements into tendering procedures, slowing down change	✓		✓						O1	1	1
		Limited decision-making autonomy in centralized tenders	In centralized procurement procedures, local decision-makers have limited autonomy; established criteria must accommodate the heterogeneous levels of environmental awareness and preparedness across participating organizations, limiting the adoption of more sustainable solutions	✓	✓	✓	✓	✓	✓	✓		G1,G2,G3,H2,I1	5	3
		Internal needs not adequately mapped	Insufficient internal needs assessment limits the ability to implement sustainable procurement practices aligned with actual operational requirements	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Inefficient order management	Limited product availability leads to frequent and fragmented orders, increasing transportation needs and environmental impacts			✓	✓					C1	1	1

Table A7 - Disaggregated limitations of current healthcare procurement models

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEPA	Direct procurement (through direct award without tender)			
Limitations of current procurement models	Economic limitations	Lack of life-cycle cost perspective	Procurement decisions focus primarily on upfront purchase costs, neglecting environmental impacts and total life-cycle costs	✓		✓	✓	✓	✓			C1,H2	2	2
		Inadequate base tender pricing	Base tender prices that are too low prevent the adoption of sustainable practices and discourage green suppliers from participating	✓		✓	✓	✓	✓	✓		B1,B2	2	1
		Cost priority over sustainability in centralized procurement	In centralized procurement models, decisions prioritize cost containment and performance, neglecting environmental sustainability criteria and penalizing solutions with higher upfront costs	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,C1,E1,H2,K1,K2,N1,N2	9	6
	Procedural limits	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	✓	✓	✓	✓	✓	✓	✓	✓	D1,F1,G1,G2,G3,H2,I1,J2	8	5
		Greater complexity in agreeing on evaluation criteria in centralized tenders	In centralized tenders, reaching agreement on evaluation criteria becomes more difficult, making it challenging to integrate sustainability aspects in a multi-organization context	✓		✓		✓	✓		✓	J1,M1,M2	3	2
		Increased bureaucratic complexity in multi-product lot tenders	In tenders with lots covering multiple products, administrative effort to monitor suppliers increases, making the integration of sustainability criteria more difficult due to limited competencies	✓				✓	✓			J1	1	1
		Lower weighting of sustainability criteria in tender evaluations	In tender procedures, sustainability-related criteria are considered but often assigned less weight than technical aspects, reducing the impact of sustainable choices	✓	✓	✓			✓		✓	K1,K2	2	1
		Lack of stakeholder involvement in tendering processes	In centralized or supra-regional procurement models, local decision-makers or specialists are often not actively involved in procurement decisions, limiting the integration of sustainability criteria	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Rigid price/quality weighting	In some procedures, such as labor or catering, fixed weightings between price and quality (e.g., 70/30) limit the flexibility needed to integrate sustainability criteria		✓			✓	✓			M1,M2	2	1
		Limited flexibility in applying sustainability criteria	High regulatory constraints in pharmaceutical procurement limit the introduction of environmental criteria, reducing decision-making flexibility, including within centralized purchasing bodies			✓	✓		✓			N1,N2	2	1
		Sustainability not decisive in tender awards	Despite minimum sustainability requirements, these do not influence award decisions compared to technical and functional specifications	✓	✓	✓	✓		✓		✓	H1,K1,K2	3	2
		Lack of sustainability expertise in tender teams	The absence of sustainability experts in tender drafting teams limits environmental criteria integration	✓	✓	✓	✓	✓	✓		✓	A1,L1,L2	3	2
		Heterogeneous sustainability choices in decentralized tenders	Different sustainability sensitivities among entities lead to heterogeneous outcomes; aggregating bodies facilitate alignment	✓	✓	✓	✓	✓	✓	✓		I1,O1	2	2
	Cultural limitations	Mindset not oriented toward sustainability	Technical bodies responsible for tender procedures neglect environmental sustainability, limiting its integration	✓	✓	✓	✓		✓	✓		C2	1	1
	Regulatory limitations	Absence of binding regulatory obligations	Existing regulations do not impose clear and binding sustainability requirements in tenders, reducing incentives	✓	✓	✓	✓	✓	✓			A1,E1	2	2
	Supply chain control related limitations	Limited supply chain control	Despite the adoption of sustainability criteria, there is limited ability to verify that suppliers effectively comply with these standards throughout the entire supply chain	✓		✓	✓		✓			H1	1	1
	Strategic limitations	Lack of an environmental procurement strategy	Current procurement models do not include structured planning or a strategic approach to integrating environmental sustainability into procurement decisions	✓		✓	✓		✓	✓		G1,G2,G3,H2,I1,O1	6	3
	Structural limitations	Intrinsic limitations of public procurement	Public procurement frameworks make it difficult to quantify and appropriately value sustainability impacts within procurement decisions	✓	✓	✓	✓	✓	✓		✓	A1	1	1

Appendix 4

Table A8 - Aggregation process of barriers, obstacles and limitations

Original disaggregated items		Disaggregated experts' frequency		Disaggregated organisations' frequency		Aggregated limiting factors		Aggregated experts' frequency		Aggregated organisations' frequency	
Themes	Keyword	Keyword description				Keyword	Keyword description				
Barrier	Higher cost of sustainable products	Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption	4	4	4	Higher cost of sustainable products	Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption	12	7		
	Difficulty justifying sustainability-related costs	Additional expenses associated with sustainable practices are difficult to justify within organizational budgets, hindering their implementation	4	2							
Barrier	Budget constraints	Budget limitations reduce procurement flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints	2	1	1	Budget constraints	Budget limitations reduce procurement flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints	4	4		
Obstacle	Economic constraints	Budget management not oriented toward sustainability, combined with higher costs of sustainable products, limits their adoption, especially in the absence of explicit regional requirements	6	3	3						
Barrier	Absence of mandatory sustainability requirements in tenders	The lack of mandatory sustainability requirements for certain products limits the integration of environmental criteria into procurement processes	7	4	4	Lack of binding sustainability-related regulations	The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects	9	6		
Obstacle	Lack of binding sustainability-related regulations	The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects	2	1							
Limitation	Absence of binding regulatory obligations	Existing regulations do not impose clear and binding sustainability requirements in tenders, reducing incentives	2	2	2	Lack of a sustainability culture	Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement	14	10		
Barrier	Lack of a sustainability culture	Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement	8	6	6						
	Public administration mindset not oriented toward sustainability	A conservative approach and limited environmental awareness within public administration reduce the adoption of sustainable procurement practices	2	2	2						
	Variable sustainability awareness	Sensitivity and awareness of sustainability issues vary among healthcare stakeholders, influencing the adoption of green procurement practices	4	3	3						
Obstacle	Lack of sustainability culture	Limited awareness and sensitivity to sustainability issues constrain the adoption of green and circular practices in procurement, especially in the absence of regulatory requirements	8	5	5	Insufficient sustainability-related competencies	A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes	10	7		
Limitation	Mindset not oriented toward sustainability	Technical bodies responsible for tender procedures neglect environmental sustainability, limiting its integration	1	1	1						
Barrier	Insufficient sustainability-related competencies	A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes	4	3	3	Sustainability requirements not effectively evaluated in tender awards	Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions	7	5		
	Need for sustainability knowledge among clinical staff	Clinical staff also need to understand environmental aspects, as procurement decisions involve multiple actors and their awareness influences sustainability integration	5	3	3						
Obstacle	Lack of sustainability knowledge	Procurement managers often lack specific sustainability expertise, limiting their ability to integrate environmental criteria and assign coherent scores	1	1	1	Sector-specific regulatory constraints	Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations	7	5		
Limitation	Lack of sustainability expertise in tender teams	The absence of sustainability experts in tender drafting teams limits environmental criteria integration	3	2	2						
Barrier	Sustainability requirements not effectively evaluated in tender awards	Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions	2	2	2	Cost-driven procurement priorities	Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices	14	9		
Obstacle	Sustainability assessment limited to certifications	Product sustainability is assessed solely based on certifications, without considering full life-cycle environmental impacts	3	2	2						
Limitation	Sustainability not decisive in tender awards	Despite minimum sustainability requirements, these do not influence award decisions compared to technical and functional specifications	3	2	2	Low base prices in tenders	Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers	4	2		
Barrier	Regulatory constraints	Binding rules and regulations may restrict the implementation of sustainable procurement practices by preventing the introduction of more sustainable solutions	4	2	2						
	Restrictions on bulk purchasing	Italian regulations prevent the purchase of pharmaceuticals without individual packaging, limiting packaging reduction and optimization of dosing and logistics	3	3	3	Lack of standardization in sustainable procurement	The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria	9	6		
Obstacle	Sector-specific regulatory constraints	Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations	3	3	3						
Barrier	Cost-driven procurement priorities	Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices	9	6	6	Lack of a life-cycle perspective	The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions	11	7		
Obstacle	Price-driven procurement culture	Procurement decisions prioritize price over sustainability, limiting the integration of green and circular practices	2	2	2						
Limitation	Cost priority over sustainability in centralized procurement	In centralized procurement models, decisions prioritize cost containment and performance, neglecting environmental sustainability criteria and penalizing solutions with higher upfront costs	9	6	6	Sustainability not considered a priority	The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority	8	4		
Obstacle	Low base prices in tenders	Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers	4	2	2						
Limitation	Inadequate base tender pricing	Base tender prices that are too low prevent the adoption of sustainable practices and discourage green suppliers from participating	2	1	1	Absence of sustainability criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	13	8		
Obstacle	Lack of standardization in sustainable procurement	The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria	1	1	1						
Limitation	Heterogeneous sustainability choices in decentralized tenders	Different sustainability sensitivities among entities lead to heterogeneous outcomes; aggregating bodies facilitate alignment	2	2	2	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	13	8		
	Lack of an environmental procurement strategy	Current procurement models do not include structured planning or a strategic approach to integrating environmental sustainability into procurement decisions	6	3	3						
Barrier	Lack of strategic vision	The absence of strategies and a life-cycle perspective prevents a systematic approach to sustainability in procurement	7	4	4	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	13	8		
Obstacle	Lack of a life-cycle perspective	The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions	2	1	1						
Limitation	Lack of life-cycle cost perspective	Procurement decisions focus primarily on upfront purchase costs, neglecting environmental impacts and total life-cycle costs	2	2	2	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	13	8		
Barrier	Sustainability not considered a priority	The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority	2	1	1						
Obstacle	Sustainability not considered a priority	Environmental sustainability is given limited consideration in procurement decisions due to the lack of priority, strategic planning, or defined objectives, constraining the adoption of green and circular practices	6	3	3	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	13	8		
Obstacle	Absence of sustainability criteria in tender specifications	Environmental sustainability criteria are absent or optional in tender documents, while technical and quality requirements prevail, reducing incentives for sustainable procurement	7	5	5						
Limitation	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	8	5	5						

Appendix 5

Table A9 - Full list of items emerging from Round 1

Themes	Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
			Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEPA	Direct procurement (through direct award without tender)			
Motivations to the integration of environmental sustainability in healthcare procurement	Environmental drivers	Reduction of environmental impacts from packaging	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,F1,H1,H2,G1,G2,G3,J1,M1,M2,J2	12	6
	Economic drivers	Reduction of waste disposal costs	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,D1,G1,G2,G3,H2,J1,L1,L2,J2	11	6
		Economic sustainability of reusable products	✓			✓	✓	✓	✓		A1,B1,B2,C1,H1,L1,L2,M1,M2	9	6
	Regulatory drivers	Regulatory requirements for sustainability	✓	✓	✓	✓	✓	✓	✓	✓	A1,D1,E1,I1,K1,K2,O1	7	6
	Personal drivers	Ethical motivations	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,C2,H1,I1,K1,K2	7	6
	Operational drivers	Logistics efficiency	✓	✓	✓	✓	✓	✓	✓		G1,G2,G3,H1,H2,N1,N2	7	3
	Environmental drivers	Waste reduction	✓	✓	✓	✓	✓	✓		✓	J1,J2,K1,K2	4	2
	Operational drivers	Reduced workload for waste management	✓		✓	✓	✓	✓	✓		F1,G1,G2,G3	4	2
	Personal drivers	Awareness of the environmental impact of products	✓		✓	✓	✓	✓			C1,H1,O1	3	3
	Economic drivers	Total cost of ownership (TCO)	✓		✓	✓	✓	✓			C1,D1,J2	3	3
	Operative drivers	Procedural benefits of sustainability	✓	✓	✓	✓	✓	✓	✓	✓	A1,L1,L2	3	2
	Environmental drivers	Environmental impacts related to purchasing volumes	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
	Economic drivers	Economic efficiency in high-value pharmaceuticals			✓		✓	✓			M1,M2	2	1
		Economic benefits of the Product-Service System	✓				✓		✓		L1,L2	2	1
	Operative drivers	Reduction of technological waste through the Product-Service System	✓				✓		✓		L1,L2	2	1
		Digitalization of processes			✓	✓		✓			N1,N2	2	1
	Environmental drivers	Less environmentally impactful production processes			✓			✓		✓	J1	1	1
	Social drivers	Social benefits of sustainability	✓		✓	✓	✓	✓			F1	1	1
	Operative drivers	Reduction of packaging	✓	✓	✓	✓	✓	✓	✓	✓	J1	1	1
	Product-related drivers	Product characteristics facilitating the adoption of sustainability	✓	✓		✓		✓	✓		I1	1	1

Table A9 (continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/REP A	Direct procurement (through direct award without tender)			
Sustainable practices	Efficient management of products and packaging	Reduction of packaging	Sustainable packaging management (e.g. use of recycled or recyclable materials and reduced packaging volumes) decreases waste generation and environmental impacts along the healthcare supply chain	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,F1,G1,G2,G3,H2,K1,K2,L1,L2,M1,M2,O1	14	8
Circular practices	Reuse	Integration of reusable medical devices	Promoting the use of reusable devices (e.g. surgical instruments or operating room materials) through safe and controlled sterilization processes extends product lifecycles, reduces waste, and lowers the environmental impact of healthcare procedures	✓	✓	✓	✓	✓	✓	✓	✓	A1,O1,E1,H1,H2,I1,M1,M2,J2	9	7
Sustainable practices	Supply chain optimization	Reduction of transport-related emissions	The adoption of low-emission vehicles and efficient transport planning reduces fuel consumption and the environmental impact of healthcare product distribution	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,F1,H2,L1,L2,N1,N2	8	5
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Application of Minimum Environmental Criteria in tendering procedures	The application of Minimum Environmental Criteria in tendering procedures ensures compliance with minimum environmental sustainability standards for procured products	✓	✓	✓	✓	✓	✓	✓	✓	J1,K1,K2,L1,L2,M1,M2	7	4
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Integration of end-of-life costs into procurement decisions	The inclusion of end-of-life and disposal costs in purchasing decisions helps reduce waste and operational costs	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,F1,H2,M1,M2	6	4
	Supply chain optimization	Logistics optimization through centralization and aggregation	The centralization of warehouses and the aggregation of deliveries enable the rationalization of transport activities, reducing waste, costs, and energy consumption in healthcare logistics	✓	✓	✓	✓	✓	✓	✓	✓	A1,B1,B2,N1,N2	5	3
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Environmental assessment of suppliers and products	Products and suppliers are selected based on compliance with environmental standards, recognized certifications, and the use of sustainable materials	✓	✓	✓	✓	✓	✓	✓	✓	E1,H2,M1,M2,J2	5	4
Circular practices	Material reduction	Procurement of products made from recycled materials	Purchasing products made from recycled materials (e.g. recycled paper) helps reduce environmental impacts and supports the circular economy	✓	✓	✓	✓	✓	✓	✓	✓	J1,K1,K2,L1,L2	5	3
Sustainable practices	Efficient management of products and packaging	Elimination of paper package leaflets for pharmaceuticals	Replacing paper package leaflets with digital solutions (e.g. QR codes) reduces paper waste and the overall environmental impact of pharmaceuticals	✓	✓	✓	✓	✓	✓	✓	✓	K1,K2,N1,N2	4	2
Circular practices	Recycle	Procurement of recyclable containers	The procurement of containers made from recyclable materials contributes to reducing waste volumes and improves the sustainability of materials management by facilitating proper end-of-life disposal	✓	✓	✓	✓	✓	✓	✓	✓	K1,K2,N1,N2	4	2
Sustainable practices	Integration of environmental incentives and requirements into tender specifications and supplier selection	Integration of sustainability criteria into tender specifications	Incorporating environmental criteria or requirements into tender specifications, through mechanisms such as award criteria or supplier incentives, steers procurement towards more sustainable or circular solutions	✓	✓	✓	✓	✓	✓	✓	✓	G2,D1	2	2
	Supply chain optimization	Bulk procurement	Procuring pharmaceuticals in bulk reduces the number of packages, minimizes packaging materials, and optimizes transportation, generating both environmental and economic benefits	✓	✓	✓	✓	✓	✓	✓	✓	E1,H1	2	2
	Efficient management of products and packaging	Reduction in the use of pharmaceutical vials	On-site preparation of pharmaceuticals limits the number of vials required, thereby reducing waste generation	✓	✓	✓	✓	✓	✓	✓	✓	K1,K2	2	1
	Efficient management of products and packaging	Pharmaceutical unpackaging (unit-dose dispensing)	Providing patients only with the required quantity of pharmaceuticals reduces waste and the environmental impact of unused products	✓	✓	✓	✓	✓	✓	✓	✓	N1,N2	2	1
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Participation in technical committees	Experts can influence the definition of Minimum Environmental Criteria by participating in technical committees within central purchasing bodies	✓	✓	✓	✓	✓	✓	✓	✓	L1,L2	2	1
	Product selection based on environmental and social sustainability	Bio-based materials	Using packaging made from bio-based materials (e.g. corn-based materials) helps reduce environmental impacts	✓	✓	✓	✓	✓	✓	✓	✓	L1,L2	2	1
	Product selection based on environmental and social sustainability	Sustainability training	Training courses on sustainability increase awareness and competencies related to integrating sustainability into procurement practices	✓	✓	✓	✓	✓	✓	✓	✓	L1,L2	2	1
	Competence development	Economic awareness among medical staff	Raising awareness among medical staff regarding product cost dynamics supports more informed and sustainable procurement decisions	✓	✓	✓	✓	✓	✓	✓	✓	M1,M2	2	1
	Competence development	Training on Minimum Environmental Criteria	Training initiatives improve understanding and application of Minimum Environmental Criteria within procurement procedures	✓	✓	✓	✓	✓	✓	✓	✓	L1,L2	2	1
	Collaboration for sustainable procurement	Provincial green procurement networks	Participation in provincial networks facilitates the sharing of sustainable procurement practices among healthcare organizations	✓	✓	✓	✓	✓	✓	✓	✓	L1,L2	2	1
Circular practices	Reuse	Replacement of cardboard packaging with reusable crates	Using reusable crates for transporting healthcare products reduces cardboard consumption and the environmental impact of packaging	✓	✓	✓	✓	✓	✓	✓	✓	K1,K2	2	1
	Reuse	Procurement of compostable products	Selecting materials that can be converted into compost at the end of their lifecycle reduces waste and the environmental impact of disposal	✓	✓	✓	✓	✓	✓	✓	✓	J1,O1	2	2
	Material reduction	Reduction in plastic use	Minimizing plastic packaging and replacing it with more sustainable materials, such as cardboard, reduces the environmental impact of transportation	✓	✓	✓	✓	✓	✓	✓	✓	N1,N2	2	1
	Material reduction	Pharmaceutical circularity	The exchange of pharmaceuticals close to their expiration date among different healthcare organizations reduces waste and environmental impacts	✓	✓	✓	✓	✓	✓	✓	✓	L1,L2	2	1
Sustainable practices	Supply chain optimization	Energy efficiency of warehouses	The adoption of solutions such as photovoltaic systems in warehouses contributes to more sustainable management of healthcare products	✓	✓	✓	✓	✓	✓	✓	✓	F1	1	1
	Supply chain optimization	Working group for monitoring Minimum Environmental Criteria	Having a dedicated team responsible for verifying that supplies and waste disposal comply with the Minimum Environmental Criteria ensures adherence to sustainability standards	✓	✓	✓	✓	✓	✓	✓	✓	J1	1	1
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Sustainability incentives in tenders	Assigning higher scores in tender evaluations to suppliers that comply with sustainability criteria promotes the procurement of lower environmental impact products	✓	✓	✓	✓	✓	✓	✓	✓	I1	1	1
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Supplier consultation to define environmental criteria	Engaging suppliers during preliminary market consultations helps identify innovative environmental criteria to be included in tenders, fostering more effective and sustainable solutions	✓	✓	✓	✓	✓	✓	✓	✓	I1	1	1
	Integration of environmental incentives and requirements into tender specifications and supplier selection	Verification of compliance with Minimum Environmental Criteria	Monitoring suppliers' compliance with Minimum Environmental Criteria during the supply phase ensures that purchased products meet the required sustainability standards	✓	✓	✓	✓	✓	✓	✓	✓	J1	1	1
	Product selection based on environmental and social sustainability	Non-toxic products	Selecting products free from hazardous substances protects the health and safety of healthcare professionals	✓	✓	✓	✓	✓	✓	✓	✓	J1	1	1
	Product selection based on environmental and social sustainability	Products manufactured using renewable energy	Procuring healthcare products manufactured through production processes powered by renewable energy sources contributes to reducing environmental emissions	✓	✓	✓	✓	✓	✓	✓	✓	O1	1	1
Circular practices	Reuse	Refurbishment of unused devices	Refurbishing unused products reduces waste and extends the lifecycle of medical devices, supporting a more circular management of healthcare resources	✓	✓	✓	✓	✓	✓	✓	✓	H2	1	1

Table A7 (continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEP A	Direct procurement (through direct award without tender)			
Barriers to green and circular practices	Economic barriers	Cost-driven procurement priorities	Procurement decisions prioritize price over sustainability, limiting the adoption of green or circular practices.	✓	✓	✓	✓	✓	✓	✓	✓	C2,D1,E1,G1,G2,G3,H1,I1,K1,K2,M1,M2,N1,N2	14	9
	Cultural barriers	Lack of a sustainability culture	Limited awareness or sensitivity toward sustainability reduces the adoption of green and circular practices in procurement	✓	✓	✓	✓	✓	✓	✓	✓	C2,E1,H1,K1,K2,I1,J1,L1,L2,M1,M2,N1,N2,O1	14	10
	Clinical preferences	Clinicians' preference for single-use devices	Clinicians tend to prefer single-use devices for reasons related to safety, convenience, and perceived effectiveness, limiting the adoption of reusable alternatives	✓			✓	✓	✓	✓		A1,C1,E1,G1,G2,G3,H1,H2,L1,L2,M1,M2,N1,N2	13	8
	Economic barriers	Higher cost of sustainable products	Sustainable products are more expensive than conventional alternatives, representing an economic barrier to their adoption	✓	✓	✓	✓	✓	✓	✓		B1,B2,C1,C2,E1,H2,K1,K2,L1,L2,N1,N2	12	7
	Lack of sustainability-related competences	Insufficient sustainability-related competencies	A lack of competencies, training, and specific knowledge related to sustainability limits the integration of environmental criteria into tender specifications and decision-making processes	✓	✓	✓	✓	✓	✓	✓	✓	A1,C1,C2,E1,H2,J1,L1,L2,M1,M2	10	7
	Organizational barriers	Sustainability not considered a priority	The absence of sustainability-related objectives or incentives at the regional level hinders the adoption of sustainable practices, making sustainability a low priority.	✓		✓	✓	✓	✓	✓		B1,B2,C2,G1,G2,G3,N1,N2	8	4
	Managerial barriers	Complexity in managing reusable devices	The introduction of reusable devices increases operational and logistical complexity, particularly with regard to sterilization pathways	✓			✓	✓	✓		✓	A1,D1,E1,H2,K1,K2,J2	7	6
	Cultural barriers	Resistance to change	Conservative mindsets and resistance to change among healthcare professionals hinder the adoption of sustainable practices	✓		✓		✓	✓			D1,H2,L1,L2,M1,M2,O1	7	5
	Procedural barriers	Sustainability requirements not effectively evaluated in tender awards	Tender specifications may include minimum sustainability requirements (e.g. environmental certifications or recyclable packaging), but these criteria do not substantially influence award decisions	✓	✓	✓	✓		✓		✓	E1,H1,K1,K2,J1,M1,M2	7	5
	Managerial barriers	Legal liability related to the sterilization of reusable devices	Legal responsibility associated with the sterilization of reusable devices makes single-use solutions a simpler option from an operational perspective	✓				✓	✓			E1,H2,M1,M2	4	3
	Economic barriers	Budget constraints	Budget limitations reduce procurement flexibility, hindering the adoption of sustainable products whose additional costs are difficult to justify within organizational budget constraints	✓	✓	✓	✓	✓	✓	✓		D1,E1,H1,I1	4	4
	Economic barriers	Lack of economic convenience of circular practices	The adoption of circular practices, such as device sterilisation, is limited by the lack of clear economic benefits, especially for low unit-cost products or when processes like sterilisation are outsourced	✓					✓	✓		B1,B2,E1	3	2
	Infrastructure and territory related barriers	Transport sustainability constrained by territorial characteristics	The geographical morphology and road infrastructure affect transport efficiency, making it more difficult to adopt sustainable logistics solutions and reduce emissions	✓	✓	✓			✓		✓	K1,K2	2	1
	Managerial barriers	Risk of product obsolescence in Product-Service System contracts	In long-term Product-Service System contracts, technological evolution and product obsolescence make it difficult to update or renegotiate ongoing tenders, limiting the adoption of sustainable solutions	✓				✓		✓		L1,L2	2	1
	Procedural barriers	Lack of standardisation of supplier certifications	The absence of clear standards for supplier certifications makes it difficult to properly assess product sustainability	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
	Product and packaging related barriers	Limited availability of sustainable products	The limited supply of sustainable products from suppliers represents a barrier to the adoption of green procurement practices	✓	✓	✓		✓	✓			M1,M2	2	1
	Managerial barriers	Limited applicability of reusable devices outside the hospital setting	Reusable devices are difficult to use by patients in home-care therapies	✓				✓	✓			D1	1	1
	Managerial barriers	Lack of warranty and maintenance for recycled non-clinical supplies	The use of recycled materials or products not supplied by the original manufacturer may result in the absence of warranties or maintenance services, creating a barrier to the adoption of more sustainable products		✓		✓				✓	J1	1	1
	Managerial barriers	Supplier orientation towards single-use devices	Suppliers tend to promote single-use products, limiting the adoption of more sustainable reusable solutions	✓				✓	✓			J2	1	1
	Managerial barriers	Single-use devices as support to reusable devices	Single-use devices remain necessary as a backup to prevent stock-outs, reducing the possibility of a full transition to reusable solutions	✓				✓	✓			J2	1	1
	Managerial barriers	Trade-off between circular and traditional surgical kits	The choice of surgical kits involves a trade-off between sustainability, through the introduction of reusable devices after sterilisation, and practicality or standardisation	✓				✓	✓			D1	1	1
	Cultural barriers	Generational barriers to sustainability	The relatively high average age of healthcare personnel contributes to lower openness to innovative and sustainable practices and greater resistance to change	✓		✓						O1	1	1
	Regulatory barriers	Lack of regulation on reusable devices	The absence of regulations allowing or incentivising the use of reusable devices limits the adoption of more sustainable solutions in the healthcare sector	✓			✓		✓			I1	1	1
	Regulatory barriers	EU-Italy regulatory inconsistency on single-use devices reuse	While EU Regulation 2017/745 (MDR) - Article 17 allows reuse after reprocessing, Italian legislation (Ministry of Health note on medical devices, 1 April 2005) prohibits the reuse of single-use devices, limiting the implementation of circular practices	✓					✓			E1	1	1
	Organizational barriers	Lack of procedural benefits	Sustainable practices do not provide immediate procedural advantages (e.g. simplification of bureaucracy or procurement timelines) for procurement offices, reducing incentives for their adoption	✓	✓	✓	✓	✓	✓			A1	1	1
	Product and packaging related barriers	Sustainability constrained by pharmaceutical product characteristics	The intrinsic properties of pharmaceuticals and the constraints of their production processes make it difficult to introduce sustainability practices, such as eco-friendly materials or alternative packaging			✓	✓		✓			I1	1	1
	Product and packaging related barriers	Lack of eco-design in packaging	The absence of packaging eco-design, aimed at reducing plastic and paper or using more sustainable materials, limits the reduction of environmental impacts	✓				✓	✓			F1	1	1

Table A9 (continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEPA	Direct procurement (through direct award without tender)			
Sustainability-related obstacles in procurement decisions	Procedural obstacles	Lack of a life-cycle perspective	The absence of a comprehensive life-cycle perspective, including disposal and waste management, hinders more sustainable procurement decisions	✓	✓	✓	✓	✓	✓	✓		C1,D1,E1,G1,G2,G3,H2,K1,K2,L1,L2	11	7
	Regulatory obstacles	Lack of binding sustainability-related regulations	The absence of mandatory sustainability requirements makes the integration of environmental criteria in tenders optional, reducing their priority compared to other mandatory aspects	✓	✓	✓	✓	✓	✓	✓		A1,E1,C1,G1,G2,G3,H1,L1,L2	9	6
	Organizational obstacles	Lack of standardization in sustainable procurement	The absence of structured and shared guidelines leaves wide discretion to individual decision-makers in defining tender requirements, leading to inconsistency and limiting the systematic integration of sustainability criteria	✓		✓	✓	✓	✓	✓		C1,E1,G1,G2,G3,I1,K1,K2,O1	9	6
	Regulatory obstacles	Sector-specific regulatory constraints	Conflicting legislative or regulatory requirements (e.g. European regulations or ministerial constraints on packaging and waste management) hinder the adoption of sustainable practices and the introduction of environmental innovations	✓		✓	✓	✓	✓	✓		E1,F1,H1,K1,K2,N1,N2	7	5
	Procedural obstacles	Limited decision-making autonomy in centralized tenders	In centralized procurement procedures, local decision-makers have limited autonomy; established criteria must accommodate the heterogeneous levels of environmental awareness and preparedness across participating organizations, limiting the adoption of more sustainable solutions	✓	✓	✓	✓	✓	✓	✓		G1,G2,G3,H2,I1	5	3
	Economic obstacles	Low base prices in tenders	Tender base prices that are set too low penalize sustainable suppliers, making it difficult for them to participate in tenders or increasing their cost disadvantage compared to conventional suppliers	✓		✓	✓	✓	✓	✓		B1,B2,M1,M2	4	2
	Market obstacles	Supply-driven market orientation	Sustainable innovation is mainly driven by suppliers, while healthcare organizations do not always define requirements that stimulate sustainable product innovation	✓	✓	✓	✓	✓	✓	✓		L1,L2,M1,M2	4	2
	Economic obstacles	Trade-off between single-use and reusable devices actual costs	The choice between single-use and reusable devices entails different impacts: single-use products increase waste generation, while reusable products generate energy and management costs that must be considered in decision-making	✓					✓		✓	K1,K2	2	1
	Procedural obstacles	Internal needs not adequately mapped	Insufficient internal needs assessment limits the ability to implement sustainable procurement practices aligned with actual operational requirements	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
	Regulatory obstacles	Short-term political vision	The lack of long-term political planning and strategic vision limits the adoption of sustainable procurement decisions, favouring short-term solutions over long-term environmental investments	✓	✓	✓	✓	✓	✓	✓		I1	1	1
	Organizational obstacles	Limited internal bargaining power	Procurement decisions are strongly influenced by clinicians, reducing the ability of procurement departments to negotiate more sustainable solutions	✓	✓		✓	✓	✓			H2	1	1
	Economic obstacles	Trade-off between social and environmental sustainability	The integration of environmental sustainability may increase costs, creating a conflict with the hospital's social objective of treating the highest possible number of patients	✓		✓			✓			E1	1	1
	Procedural obstacles	Increased managerial complexity of procurement procedures	Integrating sustainability criteria into procurement increases operational and managerial complexity for those responsible for tendering and contracting	✓		✓			✓			E1	1	1
		Difficulty in quantifying sustainability performance	Objectively measuring sustainability impacts within tender award decisions remains complex and challenging	✓	✓		✓	✓	✓			A1	1	1
		Limited recognition of sustainable suppliers	Manufacturers adopting sustainable practices receive limited benefits in centralized tenders, often gaining only reputational advantages without affecting contract awards	✓	✓	✓	✓	✓	✓			A1	1	1
		Limited availability of sustainable suppliers	The small number of companies adopting sustainable practices restricts procurement options and limits the integration of sustainability into procurement processes	✓	✓	✓	✓	✓	✓	✓		I1	1	1
		Lack of incentives for innovation	The absence of incentives or reward mechanisms reduces the attractiveness of introducing innovative and sustainable requirements into tendering procedures, slowing down change	✓		✓						O1	1	1
		Inefficient order management	Limited product availability leads to frequent and fragmented orders, increasing transportation needs and environmental impacts			✓	✓					C1	1	1

Table A9 (continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEP A	Direct procurement (through direct award without tender)			
Limitations of current procurement models	Procedural limitations	Absence of sustainability-related criteria in tender specifications	Tender specifications do not mandatorily include environmental sustainability requirements among quality criteria, preventing the full integration of environmental considerations into procurement decisions	✓	✓	✓	✓	✓	✓	✓	✓	A1,B1, B2,D1,F1,G1,G2,G3,H2,J1,J2, L1,L2	13	8
	Procedural limitations	Greater complexity in agreeing on evaluation criteria in centralized tenders	In centralized tenders, reaching agreement on evaluation criteria becomes more difficult, making it challenging to integrate sustainability aspects in a multi-organization context	✓		✓		✓	✓		✓	J1,M1,M2	3	2
	Procedural limitations	Lower weighting of sustainability criteria in tender evaluations	In tender procedures, sustainability-related criteria are considered but often assigned less weight than technical aspects, reducing the impact of sustainable choices	✓	✓	✓			✓		✓	K1,K2	2	1
		Lack of stakeholder involvement in tendering processes	In centralized or supra-regional procurement models, local decision-makers or specialists are often not actively involved in procurement decisions, limiting the integration of sustainability criteria	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Rigid price/quality weighting	In some procedures, such as labor or catering, fixed weightings between price and quality (e.g., 70/30) limit the flexibility needed to integrate sustainability criteria		✓			✓	✓			M1,M2	2	1
		Limited flexibility in applying sustainability criteria	High regulatory constraints in pharmaceutical procurement limit the introduction of environmental criteria, reducing decision-making flexibility, including within centralized purchasing bodies			✓	✓		✓			N1,N2	2	1
		Increased bureaucratic complexity in multi-product lot tenders	In tenders with lots covering multiple products, administrative effort to monitor suppliers increases, making the integration of sustainability criteria more difficult due to limited competencies	✓				✓	✓			J1	1	1
	Supply chain control related limitations	Limited supply chain control	Despite the adoption of sustainability criteria, there is limited ability to verify that suppliers effectively comply with these standards throughout the entire supply chain	✓		✓	✓		✓			H1	1	1
	Structural limitations	Intrinsic limitations of public procurement	Public procurement frameworks make it difficult to quantify and appropriately value sustainability impacts within procurement decisions	✓	✓	✓	✓	✓	✓		✓	A1	1	1

Table A9 (continue)

Themes		Keywords	Keyword description	Product categories			Procurement models					Respondents	Experts' frequency	Organisation frequency
				Medical devices	Consumables	Pharmaceuticals	Autonomous procurement (through competitive tendering by individual ASL/ASO)	Regional procurement through collaboration among multiple ASL/ASO	Regional centralized procurement through purchasing center	National procurement through CONSIP/MEPA	Direct procurement (through direct award without tender)			
Elements to redesign in current procurement models	Revision of tender parameters	Definition of sustainability criteria	Sustainability requirements to be included as evaluation criteria in tender specifications should be clearly defined in order to guide procurement decisions toward more sustainable practices.	✓	✓	✓	✓	✓	✓	✓	✓	B1,B2,C1,D1,G1,G2,G3,L1,L2,M1,M2,J2	12	7
		Separation of environmental sustainability criteria from quality criteria in procurement decision-making	Environmental sustainability should be considered as an autonomous evaluation criterion, rather than being embedded within quality criteria, and should be assigned an appropriate weight in the award process so as to influence procurement decisions alongside price and quality	✓	✓	✓	✓		✓	✓	✓	E1,G1,G2,G3,K1,K2	6	3
		Allocation of sustainability-related scores in tender specifications	Environmental criteria should be assigned a significant weight in tender scoring systems, effectively incentivizing suppliers to develop sustainable solutions, even if this may potentially reduce the number of eligible suppliers	✓	✓	✓	✓	✓	✓	✓		C1,H1,I1,M1,M2	5	4
	Greater awareness in procurement decisions	Integration of technical and sustainability-related competencies	Strengthening the role of clinical engineers and integrating professionals with environmental sustainability expertise within technical committees or working groups involved in tender design would promote a multidisciplinary approach capable of balancing technical efficiency and environmental objectives	✓	✓	✓	✓	✓	✓	✓	✓	A1,C1,J1,L1,L2	5	4
		Promotion of a sustainability-oriented culture	The implementation of initiatives and training programs aimed at increasing awareness of the environmental impacts of the healthcare sector and encouraging sustainability-oriented purchasing decisions	✓	✓	✓	✓	✓	✓	✓		E1,I1,M1,M2	4	3
	Revision of tender parameters	Bonus points for exceeding CAM	Award additional points in tender evaluation criteria to reward suppliers that exceed the Minimum Environmental Criteria (CAM), incentivizing better environmental performance	✓	✓	✓	✓	✓	✓	✓	✓	J1,K1,K2	3	2
		CAM as an innovation lever	Integrating and continuously developing CAM can encourage suppliers to propose more sustainable and innovative solutions while also reducing costs	✓	✓	✓	✓	✓	✓		✓	H2,K1,K2	3	2
		Detailed definition of sustainability criteria	Sustainability criteria should be defined with greater precision to guide procurement decisions effectively	✓	✓	✓	✓	✓	✓			M1,M2	2	1
	Strategic approach to sustainable procurement	Integration of life cycle perspective	Budgets and procurement policies should consider environmental impacts and costs throughout the product lifecycle to favor more sustainable and circular solutions	✓		✓	✓	✓	✓			A1,C1	2	2
	Innovative procurement models	Take inspiration from foreign procurement	Studying best procurement practices from other countries can help identify sustainable models and strategies applicable locally	✓	✓	✓	✓	✓	✓	✓		H1,I1	2	2
		Use of competitive dialogue	Employing competitive dialogue in tenders allows contracting authorities to discuss with suppliers additional sustainability criteria beyond the CAM and optimized technical solutions, improving market efficiency and awareness	✓	✓		✓	✓	✓			H2,J2	2	2
	Presence of experts in technical committees	Adequate composition of technical committees	Committees and technical teams should include multidisciplinary experts capable of balancing technical, economic, and environmental aspects	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Tender committees with procurement experts	Committee members could be selected among procurement and tender experts to ensure transparency and competence in evaluating sustainability criteria	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
		Certifications for tender personnel	Personnel involved in tender processes should have specific certifications, ensuring correct application of environmental and regulatory criteria	✓	✓	✓	✓	✓	✓	✓		L1,L2	2	1
	Revision of tender parameters	Guidelines from national authorities	Involve agencies like ANAC to provide official and uniform guidance for contracting authorities on integrating environmental sustainability criteria in procurement processes	✓	✓	✓	✓	✓	✓	✓	✓	J1	1	1
		Tender parameters influenced by legislation	Tender parameters should be derived from legislative indications, ensuring that sustainability criteria are incorporated into procurement documents	✓	✓	✓	✓	✓	✓		✓	A1	1	1
	Greater awareness in procurement decisions	Product environmental impact sheet	Each product should be accompanied by a producer-provided sheet quantifying its environmental impact, supporting more sustainable and transparent procurement decisions	✓		✓			✓			E1	1	1
	Greater flexibility in tenders	Availability contract	Through an availability contract, the supplier maintains full functionality of a service or product, transferring economic and management risks to the private party, improving efficiency and operational continuity	✓				✓	✓	✓		H2	1	1
	Integration of sustainable supply chain criteria	Low-impact transport requirements in tenders	Include requirements in tenders favoring the use of low-emission transport, reducing supply chain emissions	✓		✓	✓	✓	✓			F1	1	1
	Incentives to support sustainability	Allocate larger budget to sustainable suppliers	Assigning a larger portion of the budget to procurement allows prioritization of suppliers who are more aligned with environmental sustainability criteria, even if more costly	✓	✓	✓	✓	✓	✓	✓		I1	1	1
		Economic incentives for sustainable packaging	Provide financial or fiscal benefits for suppliers adopting sustainable packaging, encouraging more sustainable procurement behaviors	✓		✓	✓	✓	✓			F1	1	1