Systemic design towards user-centered sustainability in medical treatments

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Working Paper

Amina Pereno

Post-doc research fellow

Politecnico di Torino, Department of Architecture and Design

Abstract

Health systems are facing significant societal and organizational challenges that require enhancing their resilience and sustainability. The transition toward more sustainable health systems is both delicate and complex, and it needs radical changes of perspective as regards the holistic and multi-disciplinary approach to health care. Over the past years, interest in the environmental, social and economic sustainability of health care has grown globally. The present work aims at investigating the role of design towards Sustainable Healthcare, to propose, through case study experience, a systemic vision of the topic. The research methodology is deeply rooted in the framework of Systemic Design, aiming at defining how design strategies can improve the environmental sustainability of medical products, services, and systems, considering its close relationship with the social and economic aspects. Specifically, the research addressed the case study of chronic hemodialysis. In order to establish a general frame, three different dialysis units and hospitals based in different European countries (Italy, Sweden, Denmark) were compared. The comprehensive analysis of the system items making up the dialysis systems allowed to set specific guidelines for dialysis products, equipment, and treatment. The comparison of three international case studies highlighted how design should work on product and equipment to improve environmental sustainability on a global scale while addressing local systems to improve sustainability on a territorial level.

Keywords: systemic design, patient-centered care, sustainability, environment, chronic diseases, medical devices.

Introduction

Nowadays, health systems are facing significant societal and organizational challenges that require enhancing their resilience and sustainability. The impressive increase of noncommunicable diseases and long-term care is accelerating the ongoing transition towards a significant reorganization of the health systems. A paradigm shift is required to re-balance the relations between health stakeholders: people have to play an active role in their care, changing their behaviors for preventing and managing diseases. We are moving from a provider-led perspective to patient-centered care. This transition is both delicate and complex and demands a holistic and interdisciplinary approach to design products and services that will be used by new caregivers (patients) in new environments (home care). Besides technical and medical innovation, it is crucial to identify the actual needs of people to make them able to understand and use these new products and services. Usability, utility, and acceptability are leading criteria to enhance self-care and help patients to cope with the complexity of health care (Jones, 2013). The approach of design thinking to manage user-focused problems is attracting interest in healthcare stakeholders (Ticehurst, Ward, & Clarkson, 2010). Design tools and methods are perceived as useful and valid to bring innovative products and services in healthcare, starting from the social, cultural, and operational needs of users (Dorst, 2011).

At the same time, health systems are struggling to recover from the global crisis, and the need for reducing hospital expenditure is still current: this profoundly affects the innovation processes in the health sector. Economic benefits are an essential feature of all new products and services. The innovation in self-care has positive economic implications, but it alone is not enough to ensure economic sustainability. Health systems are endeavoring to optimize processes, resources, and supplies, also driven by the increasing attention to their environmental burden. The healthcare sector is, indeed, responsible for significant environmental impacts, which often represent big economic problems too: waste production and medical infectious waste, use of chemicals and disposable materials, pharmaceuticals in the environment, radioactive pollution.

Therefore, the interest in what is called “Sustainable Healthcare” has grown sharply in recent years: although in a fragmented manner, Western countries are promoting new strategies in the field of Sustainable Healthcare, encouraged by international organizations which bring together hospitals, patient associations, companies and other health stakeholders (Evans, Hills & Orme, 2012). There is no common definition of Sustainable Healthcare, but all the approaches to this topic are focusing on making health systems more environmentally, economically and socially viable. To date, policy and education research are the domains that have most addressed Sustainable Healthcare, investigating the implementation of policies and actions to foster sustainability, as well as the promotion of education programs to encourage sustainable behaviors in healthcare practice. Although design could successfully address some major environmental issues of health treatments (from waste reduction to resource optimization), the contribution of design research to this area is still very limited.

The present research investigates the role of design towards Sustainable Healthcare, aiming at proposing, through case study experience, a systemic approach to this new sector. Specifically, the research addressed the environmental issues of chronic hemodialysis, a life-saving treatment for people with chronic kidney disease. Hemodialysis has a high impact on the environment: each session uses large amounts of water and energy and produces an enormous quantity of ordinary and infectious waste. All these problems must be addressed from a system perspective since they involve products, equipment, and users, as well as the hospital system itself. A specific methodology has been defined to tackle the complexity of the dialysis system, by analyzing the different items composing the system to reach the definition of a set of design guidelines addressing Sustainable Healthcare.

Research goals

When dealing with medical treatments, we must face significant challenges because of the technical and operational complexity, that is further complicated by strict and multi-level regulations. Moreover, several people interact within the system, and design has to meet all their direct and indirect needs, to provide them with a safe and confident care experience.

At present, there is a considerable lack of research in the field of design for Sustainable Healthcare, despite design research could actively contribute to this paradigm shift in health systems. This study aims at providing its contribution to start bridging the gap between design and Sustainable Healthcare, aiming at answering two central research questions:

1. How might design strategies improve the environmental sustainability of medical products, services and systems, considering its close relationship with social (people empowerment) and economic (feasibility) sustainability?
2. How does the system affect the products and the people (patient, clinicians, health staff, technicians, and other stakeholders involved in the system) that interact with them, considering environmental sustainability? How is the local system (ward/unit) influenced by the broader context (hospital, region, country)?

Traditional design approaches cannot tackle the complexity of healthcare alone, dealing with all aspects of economic, social, and environmental sustainability. An integrated approach is needed to envision eco-innovative treatment systems. Systemic Design integrates systems thinking and human-centered design methodologies to support designers working on complex design projects in multi-stakeholder and multi-environment systems.

Research methodology

In order to answer the research questions, the study has focused on the analysis of a practical case study, that should be significant concerning relevance, diffusion, and environmental impact. Chronic hemodialysis constitutes a significant example since it involves millions of people worldwide, affected by Chronic Kidney Diseases, and it is considered as one of the most expensive medical treatments concerning care expenses, resource consumption, and waste production (Burnier & Martin, 2013).

A dialysis system consists of different items that may differ depending on the treatment method and the place where the therapy is performed. The case study analysis has been carried out in three different European countries, to ensure the replicability of the analysis and to investigate the impacts of the context on the local system:

1. San Luigi Gonzaga University Hospital, Orbassano - Piedmont Region (Italy)
2. Skåne University Hospital, Malmö - Skåne Region (Sweden)
3. Frederiksberg Hospital, Frederiksberg - Hovedstaden Region (Denmark)

The first step in the present methodology was the definition of all the items which make up the system, and the users that directly or indirectly interact with them (Figure 1). We found four items that represent four levels of the system: products (packaging, disposables, devices), equipment (dialysis machine), treatment (hemodialysis routines) and local environment (national and local policies and strategies).

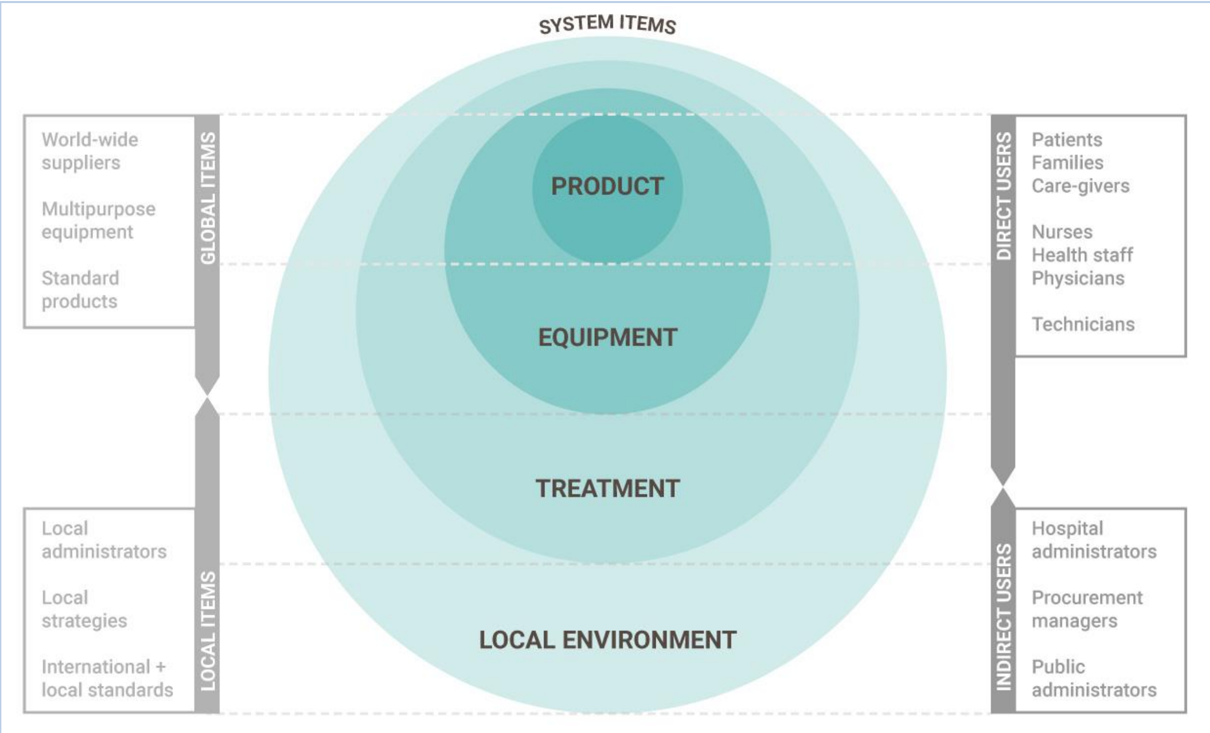

Figure 1 Visualization of the system items that make up the hemodialysis system, in relation to their global-local scale and the direct-indirect users involved

The second step is to establish the correct methods to use: we combined different approaches borrowed from sustainable design and human-centered design to analyze each item (Figure 2). The analysis of the items has followed a common methodological path that focuses on the holistic diagnosis of the current scenario (Barbero, 2017), by adopting and implementing existing design processes:

- *Process identification*. It focuses on the observation and description of the system items, understanding which processes regulate the relationships between the items and the direct users.

- *Need identification*. It defines the primary needs design has to face from a functional, social, and environmental point of view, according to each item.
- *Requirement identification*. It outlines the primary technical, operational, social and environmental requirements, starting from the identified needs.
- *Guideline definition*. It gathers and draws up the results of the previous analyses to define a specific set of guidelines for each system item.

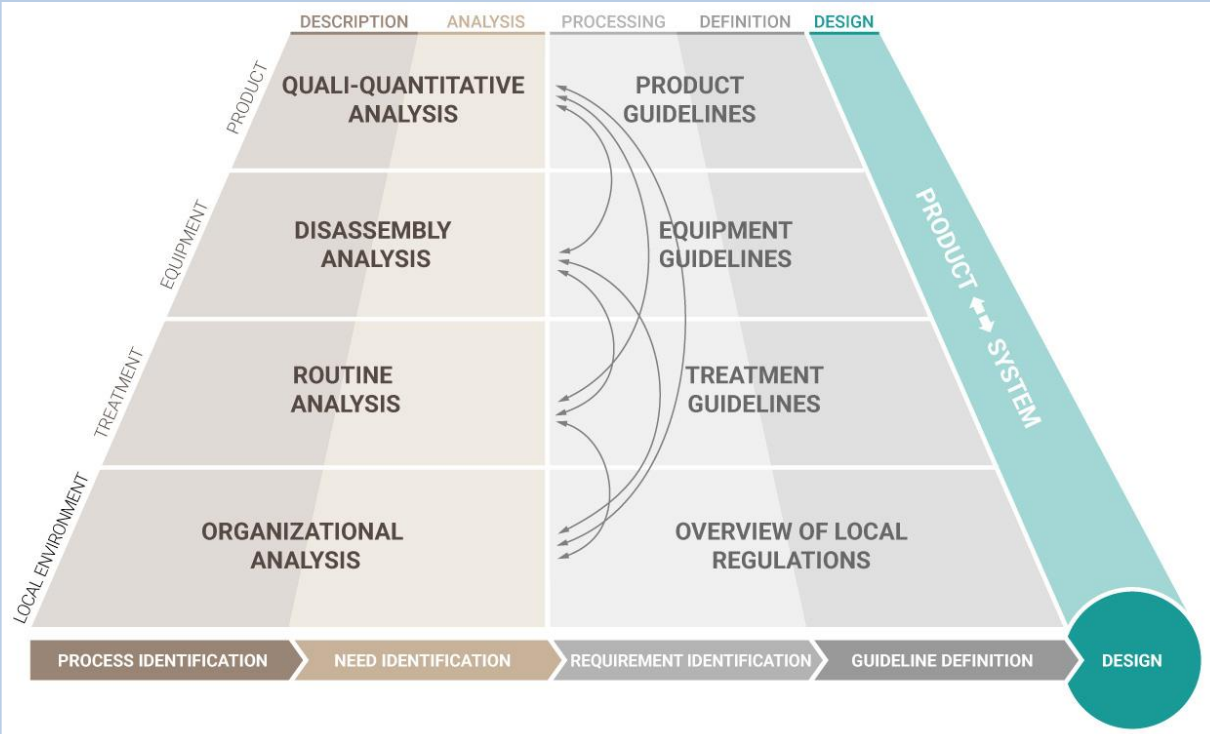

Figure 2 Visualization of the methodology implemented for the analysis of the case study.

Since the items have highly varied features, the study adopted different design methods to carry out the first two steps of analysis (Process and Need identification):

- *Product*. A qualitative-quantitative methodology has been used for analyzing packaging and products. It is a proven and field-tested method developed by the Politecnico di Torino, within the Observatory of Eco-Pack (OEP) (Barbero, Pereno, & Tamborrini, 2011).
- *Equipment*. The analysis of the equipment builds upon the well-known approaches of Design for Disassembly (Bogue, 2007) and Design by Components (Bistagnino, Marino, & Virano, 2008). This method combines the disassembly analysis with the analysis of component accessibility and input-output flows.
- *Treatment*. The analysis is based on the on-field observation (data collection and informal interview) of the treatment routines. It assesses and visualizes different tasks, starting from well-known Service Design techniques (such as patient's journey mapping tools).
- *Local environment*. The organizational analysis provides an overview of which policies and strategies are being implemented towards sustainability and how they are affecting the other items. Particular attention is paid to Green Public Procurement strategies.

Analysis of the dialysis system: findings and key issues

PRODUCT ANALYSIS

There are many methods of hemodialysis, depending on the pathology, that require different types of disposable products and packaging. The analysis assessed the qualitative and quantitative features of products, aiming at comparing different categories, methods, and case studies (Piccoli et al., 2015). The qualitative-quantitative analysis stressed different kinds of problems related to dialysis products.

First of all, products and, especially, packaging present many **functional problems** that also affect their environmental sustainability, such as product oversizing. Usability issues have a negative impact on performing nurses' tasks: difficulties in handling bulky packaging and problems in the product identification may hinder daily supply and therapy set up. The cognitive efforts required to identify and manage products also constitute a barrier to self-care and patient empowerment.

As regards the **environmental issues**, the analysis showed three main classes of problems: waste amount, waste composition, and disassembly issues. Overall, each dialysis session produces from 2 to 8 kg of waste, according to the type of treatment method, and the 95% of the non-contaminated waste fraction is made of plastics (mainly composite polymers that are much more difficult to recycle). In many cases, recyclable packaging and products are trying to separate, often because they cannot be opened and emptied of residual materials. This issue strongly affects the final weight of waste, that can increase by 43% to 315%.

Lastly, **communication issues** concern the identification of products during the supply operations, and the information about materials to facilitate waste disposal.

EQUIPMENT ANALYSIS

A hemodialysis equipment is a complex and costly machine designed for replacing the functioning of kidneys. It is used in connection with specific ancillary products. The equipment can perform different treatment methods and is designed to fit several infrastructural environments, at a global level. Therefore, the analysis has focused on the disassembly of a single equipment (Fresenius 5008) that was found to be representative of the category of in-center dialysis machines. The study was carried out with the support of the Department of Mechanical and Aerospace Engineering (Politecnico di Torino) and ACTEM S.r.l. (partner of Fresenius Medical Care), which provided technical advice on the equipment.

The equipment analysis has concentrated on components and materials (disassembly analysis), the type and ease of access to the device by technicians, nurses and patients (accessibility and interaction analysis), and the definition of inputs and outputs (flows analysis). Overall, the study put in evidence many design issues affecting accessibility, disassembly, and equipment management.

The **accessibility issues** mainly affect maintenance, because of the difficulties in accessing some internal components. This is often due to the complexity of the layout and the position of screws.

The **disassembly issues** regard the use of several types of fasteners that make components disassembly more difficult; this is also due to the lack of standards for suppliers. Furthermore, components are grouped into units that gather different materials (often WEEE) that take time to be disassembled. Little information about materials makes recycling more difficult.

Lastly, the analysis showed minor **operational issues** that mainly concern possible errors due to the access to the disinfection components by non-expert people, and the physical effort to position bloodline in the peristaltic pumps. Previous works also highlighted patient injury due to inadequate equipment disinfection and dialyzer problems (Garrick, Kliger, & Stefanchik, 2012).

TREATMENT ANALYSIS

Unlike other noncommunicable diseases, people affected by chronic kidney disease are entirely dependent on the biomedical equipment, and they need daily or weekly treatments throughout their lives. Although dialysis has always been considered as a passive treatment, nowadays both home and in-center care give patients the possibility to play a more active role in their care. Therefore, the treatment analysis has taken into account both clinicians and patients' roles, with a particular focus on patient empowerment towards self-care.

On-field observation allowed to collect data about the daily routines of nurses, patients, and physicians. The data have been visualized through a specific map, that takes inspiration from the patient journey mapping technique, and combines different task levels: routine activities, users' role, strengths and weaknesses.

The international comparison of different dialysis units highlighted specific issues that design may improve. As regards **staff tasks**, the daily activities require physical and mental efforts to supply, set-up and monitor the therapy under time pressure. Time is a key issue that product design should take into account to prevent errors in treatment set-up but also in waste sorting.

A second important point is the **role of users** in the treatment. Currently, nurses play a leading role, but the presence of physicians may limit their decision-making abilities. On the contrary, the contribution of patients to dialysis is always passive, and their awareness and decision power are still very limited. Entertainment is a crucial issue in long treatment sessions, but there is little attention to this aspect and the offer delivered by the dialysis units is absent or very limited.

Thirdly, **environmental awareness** is considered to be a relevant area to promote, but sustainable initiatives are usually poorly supported by the hospital and still strongly related to personal commitment.

ANALYSIS OF LOCAL ENVIRONMENT

Direct and indirect stakeholders are set in a highly complex context that affects the implementation of strategies and actions towards improving the environmental sustainability of the local health system.

The specific role and tasks of local stakeholders should be considered to understand how the local environment may affect the design and innovation of sustainable products, services and systems for healthcare. Therefore, a special analysis of the context has been applied to the three case studies, assessing the regional organization for Sustainable Healthcare and the implementation of Sustainable Healthcare strategies.

As regards the **regional organization for Sustainable Healthcare**, the cross-case comparison showed many significant differences concerning the organizational complexity and the presence of professional figures dedicated to environmental sustainability. In particular, environmental coordinators play a central role to put into practice the environmental strategies and practices. This is even more important to implement long-term strategies. At the same time, the complexity of the regional organization may lead to top-down initiatives, making it difficult to propose and discuss bottom-up ideas and to encourage shared responsibility among staff and patients.

Regarding the **implementation of Sustainable Healthcare strategies**, regional departments are responsible for defining the environmental programmes and the related goals to achieve. Hospitals give their feedbacks on an occasional basis. The unit staff is responsible for implementing the guidelines and strategies that regions are promoting, but their decision-making power is insufficient and their feedback is never required.

A particular analysis on **Green Public Procurement (GPP) strategies** has been carried out because of the importance of this policy tool to promote environmental sustainability in industrial design. The analysis stressed the slow pace of change in GPP and the rigidity of supply categories that could hinder the adoption of eco-innovative products and services. This may represent a major obstacle to designing systemic solutions able to integrate different items. Guidelines and strategies for Sustainable Healthcare.

Guidelines and strategies for Sustainable Healthcare

The four levels of analysis allowed to define a broad set of requirements, considering both the sustainability and the functionality of the dialysis items from a design perspective. The last step of the methodology focused on drawing conclusions from the research results, by defining a comprehensive set of **design guidelines** to provide clear and practice-based guidance for health stakeholders and company designers approaching the world of Sustainable Healthcare and, in particular, sustainable hemodialysis. In order to make their reading and comprehension easier, the guidelines have been divided into seven categories, which directly refers to Design for Sustainability (Vezzoli & Manzini, 2007) strategies: reduction (Braungart, McDonough, & Bollinger, 2008), materials (Muenchinger, 2011), technology (Thackara, 2005), flexibility (Van Nes & Cramer, 2005), usability (Maeda, 2006), lifecycle (Shedroff, 2009), and information (Scudieri & Gill, 2008).

The guidelines provide practical suggestions for designers facing the challenges of a hemodialysis system. However, the final goal of the research was to address health care and health treatments more broadly, by providing a working tool that can be made available to designers and health stakeholders approaching Sustainable Healthcare. The **design strategies** are a set of 15 strategies directed to designers and professionals, that describes the main issues of chronic treatments and the designer's role in addressing them, considering the relations between direct users (patients, health staff and technicians) and the system items:

1. Avoid or simplify packaging and overpackaging
2. Optimize machine volumes and shape
3. Prefer materials that are easier to recycle
4. Facilitate product data entry through digitization
5. Enable custom entertainment solutions for long therapies
6. Design the machine together with the device system
7. Design flexible connections for different infrastructural solutions
8. Consider maintenance and upgrade when designing the machine
9. Enhance the role of patients
10. Facilitate the daily procedure of product supply
11. Facilitate users to sort common waste and hazardous waste
12. Allow the emptying of residual materials
13. Facilitate the disassembly of machines and complex products
14. Promote environmental sustainability through communication
15. Promote users' training and autonomy

Such as for the guidelines, the design strategies refer to the seven categories of Design for Sustainability, referring to a broader framework that designers are familiar with. Strategies provide detailed information on the fundamental issues and how design can address them in relation to the system items (product, equipment, treatment) and the direct users (patient, health staff, technician) involved in a chronic treatment. Figure 3 shows the relationships between the different categories of strategies and the items and users that are involved.

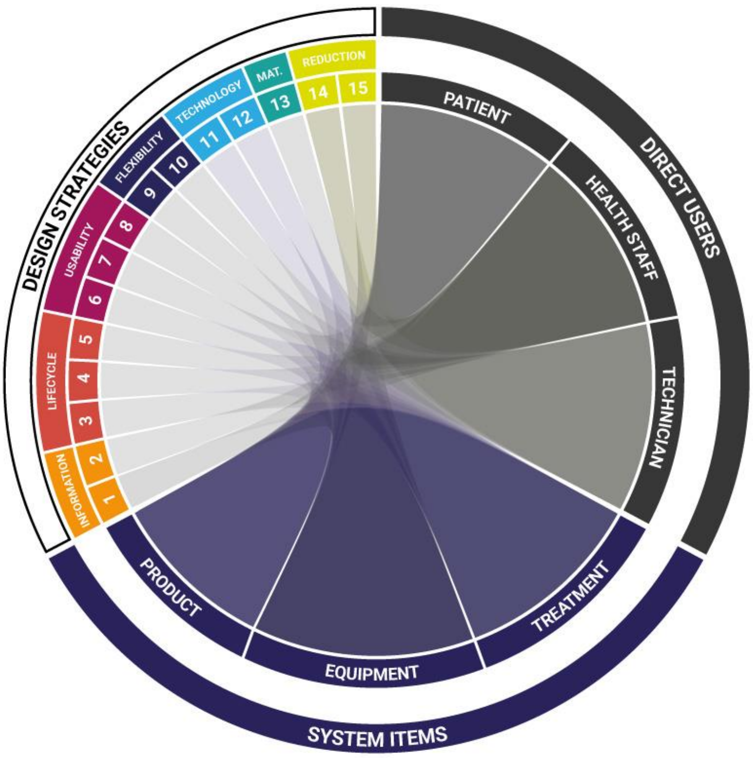

Figure 3 Overall diagram of the Design strategies, connecting categories, system items and direct users.

Conclusions

The present study has investigated the emerging field of Sustainable Healthcare from a design perspective, aiming at defining how design strategies can boost the transition towards more sustainable health systems and how these complex systems affect and relate to products, services and stakeholders.

Overall, the implemented methodology allowed to identify important strategies to boost the transition process to more sustainable and resilient system.

First of all, the **relationships that emerge between the users are the key point to improve the system**. The care experience is directly affected by the relations between the different users: designers have to identify and meet the actual needs of patients, health staff and technicians according to their activities and roles. This would increase the autonomy and awareness of users, with particular attention to patient empowerment as a primary goal of sustainable health systems.

Second, all **the material flows should be assessed from a circular perspective**: the outputs of a process can become the inputs of other systems. This shift of perspective should start from the design stage to act upstream the production process to optimize resource consumption and to prevent waste production by innovatively rethinking products and services.

Third, **an integrated vision of products and services is needed**, and design should consider products and services as parts of a broader complex system. In particular, the relation between products and medical equipment is essential to design a single integrated system that actually meets staff and patients' needs, while optimizing resource consumption.

Finally, **sustainability should be conceived as a cross-item feature of the system**. Policies cannot apply a top-down sectoral approach to environmental sustainability: design can support policymakers to broaden their perspective on sustainability, moving from the product to the system and promoting people awareness, which represents the first goal to be achieved towards Sustainable Healthcare.

In the present work, the focus on environmental sustainability allowed to deepen a specific area of Sustainable Healthcare, thus highlighting the potentialities of design research in this sector and proving the need for a Systemic Design approach to the topic. Future works must enlarge the boundaries of the present research, going into depth with the social and the economic assessment; this would allow establishing a hierarchy of design strategies, by understanding which ones should be addressed first to reach the most significant and comprehensive sustainability goals.

In the long-term, Systemic Design research should be able to move towards system flourishing, by addressing the complex system of hospital and home care. Design should provide new business models and new products and services, based on an integrated view of Sustainable Healthcare. A multi-disciplinary approach is needed to involve different stakeholders (academics, companies, public healthcare, health organizations, patient associations) in complex structured research projects.

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