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The Environmental Sustainability Assessment of an Orthopedics Emergency Hospital Supported by a New Innovative Framework

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Abstract: Due to their high consumption of resources and enormous amount of generated waste, healthcare systems are not considered to be sustainable. Given the constant changes in internal needs, improvement of this state cannot be achieved only through policies, strategies, and interventions administered from the outside. Thus, it is necessary to design tools that, through their constant application, facilitate the sustainable development of health institutions. The objective of this research is to develop and validate in practice an innovative framework for assessing the sustainability of healthcare facilities that is compatible with hospital accreditation legislation and other community frameworks. The research is limited to the study of environmental sustainability and its results are validated in a healthcare facility with an orthopedic profile. The research method consists of defining the domains of the new innovative framework, collecting the latest medical practices related to environmental sustainability, designing indicators related to environmental responsibility and a matrix of indicators, followed by its validation in practice at an emergency hospital. The new innovative framework is organized in three areas, including environmental, economic, and social sustainability, to which is added organizational capacity along with management and provision of sustainable healthcare services. It contains 57 indicators, of which 8 are dedicated to the environmental area. The indicators are described in detail together with evaluation grids structured by the coupled degrees of importance and achievement. The practical implementation of the innovative framework at the County Emergency Clinical Hospital of Targu Mures highlights its added value by promoting sustainability strategies together with continuous quantification of the organization's sustainability level.

Keywords: environmental sustainability; sustainable development; innovative framework; assessment; orthopedics department; healthcare facility

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1. Introduction

The stated objectives of health policy at the community level are to promote good health, protect citizens from threats, and support sustainable development. New technologies have the potential to revolutionize healthcare systems and contribute to their sustainability in the future. This transformation requires the coexistence of society in harmony with the natural environment by protecting it from irreparable destruction and achieving balance with the current way of existing. This is characterized by economic growth based on the consumption of natural resources and environmental protection through the discovery and use of new alternative resources.

Currently, healthcare systems are not considered to meet the criteria of sustainability because they consume large amounts of resources and generate enormous waste. This state cannot be improved sustainably through interventions administered from outside the system, since internal needs are constantly evolving [1].

At the moment, health promotion and sustainable development strategies are not sufficiently well integrated. The current policies for solving health and environmental problems cause unwanted and unanticipated new health and environmental problems [2].

The sustainability of public health programs is poorly addressed in global policies [3]. Strengthening national and international sustainability policies and incorporating them into public health planning frameworks can create an environment that better enables local programs. Their long-term sustaining effects are essential to ensure full manifestation of the expected benefits. To evaluate the viability of healthcare facilities, indicators such as efficiency, energy savings, etc. can be used [4].

To quantify sustainability, Maine [5] suggests restricting use of the term to physical processes as the only way to obtain a reliable and robust metric. An important attribute that any system requires to become sustainable is minimal "waste" production or "the amount of energy not used to recover waste." A number of sustainability indicators are based on "emergent synthesis," as introduced by Odum [6]. It expresses the cost of a process or product in equivalents of solar energy, which is considered the final source of energy.

Sustainability has become a basic criterion in the evaluation of public health programs. Yang et al. [7] advocate for a reconceptualization of sustainability criteria in light of the idea that health is an investment that is itself sustained and sustainable. They suggest abandoning sustainability conceptualizations that focus on consumable medical interventions that enable health status. In this context, sustainability is appreciated as a cross-sectoral approach that supports the essential symbiosis between human activity and the environment. The challenge is the large-scale promotion of sustainable development policies in relation to conventional economic growth [8].

After exploring the specialized literature, we found that a series of studies have presented conceptual and practical developments regarding sustainability by focusing on specific aspects that can make medicine more eco-friendly. An example is the study by Savoldelli et al. [9], which indicates telemedicine as having this potential. Malone et al. [10] developed a clinical sustainability assessment tool with the resulting conceptual domains: engaged staff and leadership, engaged stakeholders, monitoring and evaluation, organizational context and capacity, workflow integration, planning and implementation, and outcomes and effectiveness. The authors collected suggestions from 64 specialists in clinical and research fields, holding a brainstorming session to identify sustainable medical practices. However, we appreciate that the suggestions formulated were not fully validated in practice through implementation in representative medical units, which is why in this research we have proposed to collect sustainable practices reported in the literature and confirm them in current practice in hospitals.

A literature review by Lennox et al. [11] identified 32 frameworks, 16 models, 8 tools, 4 strategies, 1 checklist, and 1 process related to sustainability approaches in healthcare. The paper states that there is no clear consensus on how to define or influence sustainability or a framework for it. Little has been done comprehensively about sustainability in medical environments [12–14].

Other studies identify indicators without defining their content or presenting a method for evaluating them. The study by Molero et al. [15] can be included here, which set 7 environmental, 6 social, and 7 economic performance indicators for clinical laboratories.

Our study addresses the identified gaps in previous research and attempts to answer the following questions:

> *What are the successful environmental sustainability activities reported in the scientific literature by internationally representative healthcare facilities? What indicators can be defined in order to form a comprehensive innovative framework for environmental sustainability assessment? How can the indicators of the innovative framework be*

qualitatively and numerically defined in such a way as to enable the assessment of organizational sustainability and allow the tracking of implementation progress?

Based on these research questions, the main objective of this research was to develop and make available to healthcare facilities a new complex tool for the evaluation of organizational sustainability, in particular, the evaluation of environmental sustainability. It has the form of an innovative framework through which healthcare managers and professionals may develop new strategies for sustainable development. The secondary objective was to ensure that the new innovative framework is compatible with the accreditation legislation and frameworks currently used in healthcare institutions. This has the added value of promoting sustainable development.

In this study, research is carried out regarding sustainability but it is limited to environmental aspects. The healthcare facility in which the research results are validated is an emergency hospital with an orthopedic profile. Other limitations of the study are formulated at the end of the discussion section of this paper.

2. Materials and Methods

The exploratory research methodology applied in this study consisted of:

1. Defining the fields of the new innovative framework by integrating environmental, economic, and social sustainability requirements along with sustainable medical practices, which are organized into the four steps of the quality cycle;
2. Collecting the latest medical practices from hospitals related to environmental sustainability that are reported and confirmed in international scientific studies by exploring the relevant databases and studying the latest medical scientific literature;
3. Conceptualizing the content and evaluation grids of environmental responsibility-related indicators based on the successful healthcare practices extracted from the knowledge-based literature;
4. Conceptualizing an indicator matrix of the innovative framework by establishing connections between the basic medical activities organized in the sequence of the quality cycle and the core subjects of the social responsibility standard;
5. Validation in practice of the innovative framework through implementation and self-evaluation at an emergency hospital.

The theoretical foundation of the research is primarily based on the principles of systems thinking in which sustainability is defined by three interconnected environmental, economic, and social pillars. With this support, we describe and explain the socio-ecological phenomena of healthcare facilities. We also use the general theory of business administration and management functions. By employing the concept of key performance indicators in evaluations, we reflect the critical success factors of healthcare facilities. The method of organizing and carrying out management activities according to the quality cycle facilitates the orientation of healthcare facilities towards continuous improvement. The theory of organizational social responsibility is also integrated.

2.1. Innovative Framework Areas

The research started by establishing the areas of the innovative framework related to sustainable development. For this, we explored the medical scientific literature and found that along with the three areas of sustainability, there is a need for effective management enhanced by good organizational capacity [16]. For this reason, we included a fourth area of sustainability, entitled organizational capacity and management.

Reference frameworks in the field of healthcare also have to address the quality assurance of medical services, as presented by Isaksson [17]. Taking into account this observation, along with the areas previously indicated, we incorporated a fifth area describing sustainable healthcare service delivery. This ensures the quality of medical practices, comprising the basic processes of the organization.

In this way, the conceptual model of the Health-Sustainability (H-S) innovative framework (Figure 1) included, along with the three sustainability areas (environmental, eco-

nomic, and social), two other areas: organizational capacity and management and provision of sustainable healthcare services.

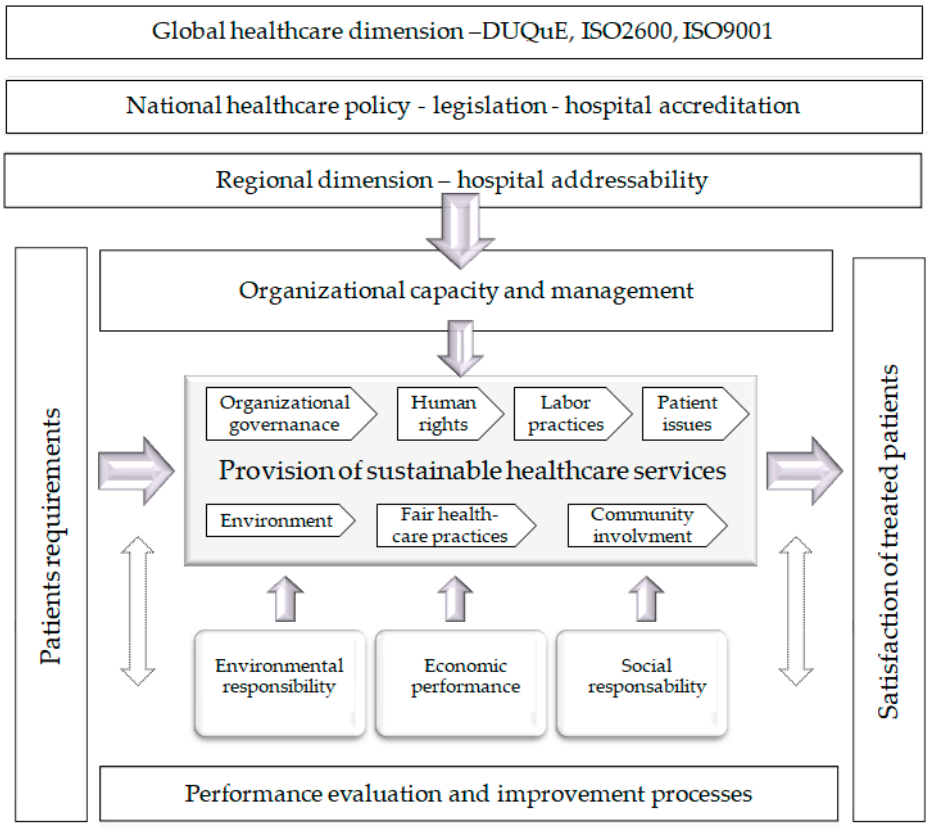


Figure 1. The conceptual model of the Health-Sustainability (H-S) reference framework [18,19].

The economic pillar is outlined by the contracting policies of medical services, financial performance, investment policy, economic control, and risk management. It must encourage and promote environmental protection by limiting the risks posed by activities within healthcare facilities. Fundamental aspects of the economic pillar of sustainable development are the recycling of products and use of renewable energy. The social pillar of the sustainable development of healthcare facilities refers to the values that promote equality and respect for the individual rights of patients and medical staff. These aspects are used to assess social consequences such as gender equality. The environmental pillar is based on the commitment to protect the environment by reducing risks and measuring the impact of the healthcare facilities' activities. Objectives must be established that are an integral part of the corporate social and environmental responsibility and that contribute to improving performance on environmental issues.

The last area that describes the basic medical processes includes the seven core subjects of the ISO 26000 standard on social responsibility [18]. We have adapted them to medical specifics: (1) organizational governance, (2) human rights, (3) labor practices, (4) the environment, (5) fair healthcare practices, (6) patient issues, and (7) community involvement and development.

The model of the H-S framework developed in this research was compatible with the ISO 9001 quality management standard [19], national legislation and procedures for the accreditation of hospitals [20], outpatient healthcare services [21] of the quality regulatory authority in the national system of health of Romania (ANMCS), and also with the DUQuE reference framework, which aims to improve quality assurance and patient safety in European hospitals [22].

We continued the research by designing the basic medical activities related to the four stages of the quality cycle: plan (healthcare service design); implement (healthcare service

provision); evaluate (healthcare service evaluation); review (continuous improvement). Thus, we designed eight core medical activities, two for each of the four stages of the quality cycle [23]. In the planning phase, we created the activities healthcare service accreditation (PA) and patient-centered care intervention design (PB). In the next phase of implementation, we created the activities healthcare service provision (IA) and transfer assurance (IB). In the evaluation phase, we created the activities evaluation and involvement of local opinion leaders (EA) and satisfaction assessment (EB). The last review phase was composed of the activities self-assessment (RA) and healthcare service innovation (RB). By aggregating these results, we represented the four stages of the quality cycle structure together with succession and interconnection of its eight activities, as shown in Figure 2.

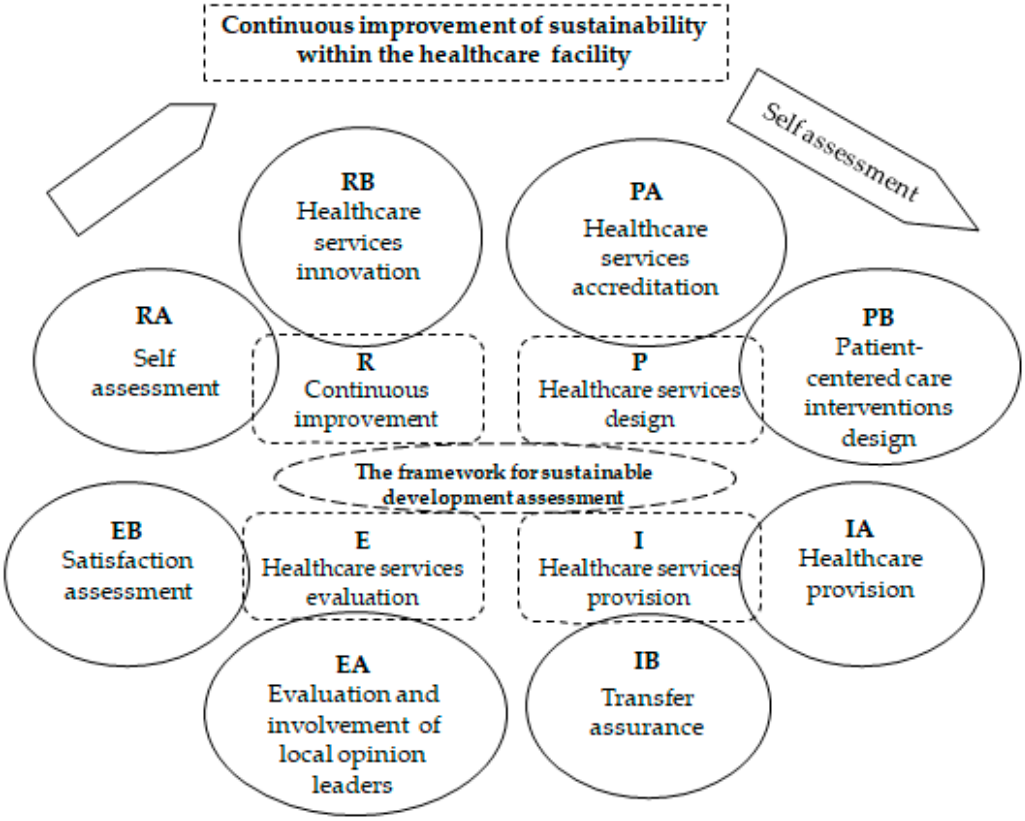


Figure 2. The succession and interconnections in the quality cycle of basic medical activities: P—plan; I—implement; E—evaluate; R—review.

2.2. Evidence of Environmental Sustainability in Healthcare Organizations

In the next step of the research, we defined the content and evaluation grids of the indicators that comprised the area of environmental sustainability within the new innovative framework.

For this, we explored the scientific literature from relevant medical databases, such as PubMed, EMBASE (OVID), and Web of Science, in order to extract evidence of environmental sustainability in healthcare organizations. The research was conducted using keywords related to sustainability, the environment, medical practices, and healthcare facilities. Recent articles published primarily within the last 10 years were selected. We only included articles in the study that presented new knowledge, recent discoveries, clinical studies, and environmental organizational strategies, with results confirmed by evidence from practice in healthcare facilities. In the next stage of the research, we compared the articles and extracted the practices that were in accordance with the objectives of our study. In cases that described several activities referring to the practical implementation of the

same requirement related to environmental sustainability, we selected the most general practices that allowed follow-up on the analyzed process evolution.

In this way, we obtained confirmed evidence of the best medical and organizational practices related to environmental responsibility that have been tested in the most representative medical facilities.

2.2.1. Indicators for Healthcare Service Design

Although impact assessments on the environment and use of natural resources are starting to be carried out at the level of healthcare systems and individual hospitals, there is not enough detailed information to make decisions that orient these institutions towards sustainability [24].

Ingrassia et al. [25] showed that it is necessary to develop standards, guidelines, and procedures at the national level to improve the preparedness of hospitals for disasters. Wurm et al. [26] described the entire process of developing a hospital's emergency plan to properly prepare it for such situations.

Most countries have equipped hospitals against chemical incidents, but some aspects remain challenging, such as databases, response team members, communication, etc. [27]. Rebmann et al. [28] suggested that hospitals should use appropriate planning tools to support the development of intervention plans. Zhang et al. [29] proposed using whole-cell bioreporter technology to streamline short-term environmental impact assessment, and Jarousse [30] presented specific steps that hospitals can take to reduce their environmental impact.

Munasinghe et al. [31] identified some important preparation themes for action in case of disasters, which were structured according to the components of the 4S framework: space, stuff, staff, and systems. Preparing hospitals for biohazards is one of the most important organizational disaster plans [32]. In disasters and emergencies, a hospital's surge capacity plays a significant role in reducing mortalities and increasing the treatment rate of severe injuries [33]. Surge capacity is a basic element of disaster preparedness programs [34].

Establishing an operating room committee dedicated to green initiatives can improve the environmental impact of healthcare [35].

We used the previously described practices as input elements for the design of the environmental impact plan indicator (see Table A1 for a detailed description of indicator PA4—environmental impact plan), which is part of the basic medical activity termed healthcare service accreditation.

By promoting energy efficiency programs, green building designs, alternative energy sources, low-carbon transportation, local food, waste recycling, and water conservation, the health sector can develop several key strategies to become greener [36]. Until now, no clinical practice guidelines have been developed to promote and implement climate-smart actions. Improving awareness and education is important to act collectively in a sustainable manner [37].

Healthcare facilities are a significant source of pollution worldwide and contribute to environmental change, but the surgical field has a unique opportunity to adopt greener operating strategies [38]. Responsible anesthetic management options should recommend inhalational anesthesia. The use of minimal or metabolic flow of fresh gas significantly reduces the intake of anesthetics. Nitrous oxide (N_2O) should be avoided entirely as it contributes to depletion of the ozone layer, and desflurane should only be used in justified exceptional cases [39]. Lindén-Søndersø et al. [40] showed that the carbon footprint can be reduced by 73% by replacing desflurane with sevoflurane. By replacing sevoflurane with intravenous propofol, the climatic effect can be further reduced by at least two orders of magnitude. Desflurane has a greater potential impact on global warming than isoflurane or sevoflurane. Only N_2O produces a considerable greenhouse gas contribution relative to sevoflurane or isoflurane. Avoidance of N_2O and unnecessarily high fresh gas flows can reduce the environmental impact of inhaled anesthetics [41].

Physicians should avoid unnecessarily high fresh gas flows for all inhaled medications. They should primarily use residual anesthetic gas capture systems. Sherman et al. [42] showed that other techniques, such as total i.v. anesthesia, neuraxial, or peripheral nerve blocks, are less harmful to the environment.

We used the previously described practices as input elements for the design of the environmental criteria for selection of materials used in interventions indicator (see Table A3 for a detailed description of indicator PB4—environmental criteria for selection of materials used in interventions), which is part of the basic medical activity termed patient-centered care intervention design.

2.2.2. Indicators for Healthcare Service Provision

The majority of regulated medical waste is generated in the operating theater through single-use surgical materials (e.g., drapes, gowns, basins, gloves, sponges) [43]. Reusable products are preferable to disposable ones. Reusable products reduce regulated medical waste by an average of 65%, as well as waste disposal costs [44].

A comparison between reusable and disposable perioperative textiles reflects major changes in production technologies. Overcash [45] claimed that reusable surgical gowns and drapes bring important improvements in sustainability.

Examining life cycle criteria in the device selection decision-making process can raise awareness of the negative impact of healthcare practices on the environment. Eckelman et al. [46] found that laryngeal masks, which are reusable on average 40 times, have a more favorable environmental profile than disposable masks. The most important sources of impact for single-use laryngeal masks are polymer production, packaging, and waste management. On the other hand, washing and sterilization dominate most impact categories for reusable laryngeal masks. Operating procedures can ensure that reusable laryngeal masks are not discarded prematurely [46].

Tonsillectomy/adenotonsillectomy cases use many disposable supplies that are not recyclable. Penn et al. [47] observed that disposable articles were prepared and available in cases of tonsillectomy, but almost never used. Meiklejohn and Chavarri [48] quantified the disposable equipment required for tonsillectomy by monopolar electrocautery, the coblation technique, and the cold technique. They found that the cold technique produces the least waste and has the lowest cost attributed to disposable surgical equipment.

We used the previously described practices as input elements for the design of the usage of recycled materials indicator (see Table A5 for a detailed description of indicator IA41—usage of recycled materials), which is part of the basic medical activity termed healthcare service provision.

The healthcare industry is second only to the food industry in terms of annual waste production [49]. Waste disposal also accounts for up to 20% of a hospital's annual environmental services budget. The operating room disproportionately contributes around 30% to 70% of total hospital waste [50]. Anesthetists could take a leadership role and work with other hospital staff to improve recycling in operating rooms [51].

Up to 90% of the waste generated from orthopedic interventions in the operating room is improperly sorted and sent for costly and unnecessary hazardous waste processing [52]. In orthopedics, the successful reprocessing and reuse of external fixators, razors, blades, burs, and tourniquets are beneficial from an ecological and economic point of view [52]. Infectious medical waste can present a real risk to the health of patients and staff because microorganisms can survive on non-living surfaces [53]. By implementing small iterative changes in radiological practice, financial savings can be achieved, improving healthcare and environmental sustainability [54].

Every producer of controlled waste has a duty to dispose of it [55] in a way that minimizes the risks to public health and the environment [56]. The waste management plans of healthcare facilities must include waste separation and management [53]. Greening initiatives include reducing, recycling, reusing, rethinking, and research, as well as new technologies and smarter architectural design [57].

Infectious and non-infectious medical waste can be treated on site to destroy the harmful content [58]. Medical waste sterilizers are an eco-friendly method of thermal disinfection. The optimal method for centralized disposal of medical waste is thermal processing of the collected material [59]. On-site incineration reduces the weight and volume of solid waste by 90% to 95%, sterilizes pathogenic waste, detoxifies chemical waste, and converts harmful waste to harmless ash [60]. Although ballistic gloves provide protection against sharps injuries, the disposal of hypodermic needles exposes waste handlers to the risk of infection with blood-borne viruses [61].

We used the previously described practices as input elements for the design of the waste recycling indicator (see Table A7 for a detailed description of indicator IA42—waste recycling), which is part of the basic medical activity termed healthcare service provision.

2.2.3. Indicators for Healthcare Service Evaluation

Patients who are transferred between hospitals face high risks of adverse events and mortality. Organizational structures are not sufficiently developed to ensure that patients are optimally referred [62]. Abraham and Reddy [63] showed that the transfer flow of patients is affected by inefficient inter-departmental interactions, information transfer, and information technology.

Important technological advances now make it possible to identify the most capable nearby hospital to help critically ill patients and ensure their successful transfer. To identify the optimal destination, Haque et al. [64] proposed a solution that uses business intelligence techniques to analyze data related to healthcare infrastructure and services.

For older adults moving between healthcare settings and clinicians, the transitional care model risks poor outcomes because it is managed by nurses alone [65]. The level of communication between the emergency department and primary care area is inadequate. There is confusion about aftercare and a lack of support for older people upon discharge [66]. Most critically ill patients are handled by medical staff, which increases patient discomfort and can cause skeletal and muscle injuries [67]. To prevent these shortcomings, Sun et al. [68] designed a patient transfer device.

The interhospital transfer practices that should be most used are: electronic medical records [69,70], cross-talk availability and utilization, real-time transfer center documentation accessibility in the electronic medical record, and referring center clinical documentation availability prior to transportation [71].

Usher et al. [72] showed that completeness of patient transfer documentation may be associated with improved outcomes and appropriate use of resources for patients transferred between hospitals. With the aim of meeting criteria that guide safe transfer for all patients leaving hospital, Hindmarsh and Lees [73] designed a "transfer checklist".

We used the previously described practices as input elements for the design of the environmentally friendly transfer interventions indicator (see Table A9 for a detailed description of indicator IB4—environmentally friendly transfer interventions), which is part of the basic medical activity termed transfer assurance.

2.2.4. Indicators for Continuous Improvement

There are a number of means and programs through which hospitals have improved their environmental consumption. They have eliminated single-use canteens and eating utensils from cafeterias, switched to reusable drapes and surgical linens, and established recycling programs for paper and cardboard [74]. Kirkland et al. [75] provided information and examples of cooling technology selection. Koch and Pecher [76] showed that improving environmental consumption can be achieved by applying energy-saving techniques, proper waste management, and using sustainable energy sources. Sattler and Hall [77] suggested some recommendations for adhering to environmentally preferred purchasing policies, applying environmental strategies related to waste management, reducing the use of chemical pollutants, and promoting healthy foods.

Due to the large volumes of resources consumed and waste produced, operating rooms are a major contributor to the carbon footprint of a hospital [78]. Sullivan et al. [79] proposed quality improvement initiatives that reduce both the costs and environmental impact of these facilities. Bravo et al. [80] proposed several ways to reduce both tangible and intangible residual energy consumption, sterilization techniques, device reprocessing, patient transport, surgical supplies, anesthesia, and sanitation in hand surgery. Dioxin from plastic medical sources is reportedly the dominant source of chlorine in the medical waste stream [81]. Álvaro-Meca et al. [82] showed that there is an association between short-term exposure to environmental factors and increased risk of hospitalization for sepsis-related pneumonia.

Environmental sustainability in orthopedic surgery is a growing field with great potential for change. Phoon et al. [83] showed that the environmental impact of orthopedic surgery is mainly due to the low degree of waste recycling. The largest amount of recyclable waste per procedure is generated by large joint arthroplasties. The authors also showed that simple changes in practice can reduce water consumption by up to 63%.

We used the previously described practices as input elements for the design of the improvement of environmental consumption indicator (see Table A11 for a detailed description of indicator EA4—improvement of environmental consumption), which is part of the basic medical activity termed evaluation and involvement of local opinion leaders.

Hospitals consume a lot of energy and resources. Operating rooms contribute a large proportion of emissions due to the use of anesthetic gases, energy-consuming equipment, and waste [84]. An analysis of energy data from Norway's newest hospital showed that electricity consumption comprised up to 50% of the energy used for the entire building. Much of this is due to the increasing energy use intensity of hospital equipment [85].

Hospitals are motivated to adopt a green ideology due to rising energy costs, the need to replace old facilities, and a growing environmental consciousness [86]. Options for adopting sustainability and green principles extend to every aspect of a hospital's operations [87]. Green practices refer to decreasing energy consumption, using resources carefully and sustainably, and reducing environmental pollution. An environmentally friendly hospital is defined as a hospital in which energy is saved, carbon emissions are reduced, and productivity and quality are increased [88]. To date, most hospitals have engaged in some strategy to improve environmental performance, such as reducing energy or landfill waste [89].

Through a screening study, Sundell-Bergman et al. [90] determined public exposure from hospital discharge into public sewers. They showed that doses were higher than normally allowed for those who work in sewers. McGain et al. [91] quantified the long-term electricity and water consumption of a hospital steam sterilizer. They presented opportunities to improve sterilizer efficiency by rotating idle sterilizers and reducing the number of light loads. The data presented are useful for life cycle assessments of all reusable steam sterilizer equipment.

We used the previously described practices as input elements for the design of the mechanisms for monitoring energy consumption and waste generation indicator (see Table A13 for a detailed description of indicator RA4—mechanisms for monitoring energy consumption and waste generation), which is part of the basic medical activity termed self assessment.

Álvaro-Meca et al. [92] showed that, among the elderly, the chances of hospitalization with lower respiratory tract viral infection was increased upon exposure to unfavorable environmental factors such as high humidity, low temperatures, and high concentrations of CO, PM10, O_3, and NO_2.

Lee et al. [93] showed the correlation between hospital admissions of young children with acute lower respiratory tract infection and exposure to polluted air. To plan public health resources, it is important to monitor environmental factors [94].

The healthcare industry is faced with a complex set of regulations related to the management of medical waste disposal in terms of packaging, transportation, and environ-

mental regulations for medical waste incinerators [95]. To protect public health, hospital incinerators should be equipped to reduce atmospheric emissions [96]. A reduction in the amount of incinerated waste results in a lower level of emitted pollutants such as dust, dioxins, As, Cd, Cr, Mn, and Ni [97]. Careful segregation of waste, as well as attention to purchased materials, is essential for minimizing the environmental and health impact of any technology [98].

Piersanti et al. [99] assessed radioactivity concentration levels in hospital wastewater, planned their suppression, and optimized management procedures. Significant potential to reduce transport-related emissions could be achieved by replacing face-to-face hospital visits with telemedicine [100].

Future improvements in hospital organizational frameworks for e-health can only be made with an improved understanding of the socio-technical theoretical framework and natural hospital environment context [101]. By applying shared governance models, nurses can reduce the overhead costs associated with management [102].

We used the previously described practices as input elements for the design of the environmental measures indicator (see Table A15 for a detailed description of indicator RB4—environmental measures), which is part of the basic medical activity termed healthcare service innovation.

2.3. Designing the Content of the Indicators and the Evaluation Model

We continued this research by designing the content of the 57 indicators that comprised the new innovative framework, collecting detailed descriptions of successful clinical practices reported in the medical scientific literature.

In order to easily evaluate the degree of fulfillment of the indicators, we developed a group of fundamental questions for each indicator (see Tables A1, A3, A5, A7, A9, A11, A13, and A15 for the environmental indicators). The evaluation of the answers received by the auditor was carried out on a scale with 6 steps that allowed two categories of quantification: both numerical (through the values 0–5) and qualitative (through the assessments of not relevant, low, satisfactory, good, very good, and excellent) (see Tables A2, A4, A6, A8, A10, A12, A14, and A16 for the environmental indicators).

To this was added the degree of importance of the indicator, also assessed both numerically (through the values 0–5) and qualitatively (through the assessments of not relevant, unimportant, reduced importance, important, very important, high importance). Each of these was defined as the indicator having lower importance for the organization or that its non-fulfillment may lead to compromising the activity within the healthcare facility, as seen in Table 1.

With this, we developed a new innovative numerical and qualitative evaluation of organizational performance. This was supported by the indicators through coupling the values that described their degrees of importance and achievement.

For reasons of space limitations and to facilitate the understanding of the evaluation methodology, Appendix A (Tables A1–A16) presents the detailed descriptions and innovative evaluation grids of the eight indicators that describe environmental sustainability, as follows: Table A1. The indicator PA4—environmental impact plan; Table A2. Scale for indicator PA4—environmental impact plan; Table A3. The indicator PB4—environmental criteria for selection of materials used in interventions; Table A4. Scale for indicator PB4eEnvironmental criteria for selection of materials used in interventions; Table A5. The indicator IA41—usage of recycled materials; Table A6. Scale for indicator IA41—usage of recycled materials; Table A7. The indicator IA42—waste recycling; Table A8. Scale for indicator IA42—waste recycling; Table A9. The indicator IB4—environmentally friendly transfer interventions; Table A10. Scale for indicator IB4—environmentally friendly transfer interventions; Table A11. The indicator EA4—improvement of environmental consumption; Table A12. Scale for EA4—improvement of environmental consumption; Table A13. The indicator RA4—mechanisms for monitoring energy consumption and waste generation; Table A14. The indicator RA4—mechanisms for monitoring energy consumption and waste

generation; Table A15. The indicator RB4—environmental measures; Table A16. Scale for RB4—environmental measures.

Table 1. Importance of the indicators.

Value [S]	Importance Category	Description
0	Not relevant	X
1	Unimportant	The subject is of little importance to the healthcare facility and there is a marginal tendency for evaluation.
2	Reduced importance	Failure to comply with this requirement could adversely affect the activity of the healthcare facility.
3	Important	Failure to comply with the requirement could compromise the activity of the healthcare facility. It is essential to meet the requirements of the healthcare facility.
4	Very important	Failure to meet this requirement could jeopardize the successful provision of healthcare. Fulfilling the requirement is essential for the successful delivery of healthcare.
5	High importance	Failure to comply with the requirement may even compromise the existence of the healthcare facility.

As an example, we present how indicator PA4 (environmental impact plan) is defined in Table A1, which refers to the environmental impact reduction schemes that were developed in relation to the scope. The questions formulated for its evaluation were: Are you aware of the impact of your healthcare activities on the environment (atmosphere/soil/water)? Are the activities carried out polluting the atmosphere and/or soil and/or water? Are there greenhouse gases emitted into the atmosphere? Is the impact of waste on the environment known? How are they considered and what actions are set? Is there concern in the organization regarding the environmental impact on water, or are these effects taken into account? If so, how? What treatment is applied to organic waste? What treatment is applied to inorganic waste? What treatment is applied to toxic waste?

The evaluation scale for indicator PA4 (environmental impact plan), presented in Table A2, consists of the scores: 1 (low): The impact of own healthcare activities on the environment (atmosphere/soil/water) was estimated, but no initial environmental analysis was carried out; 2 (satisfactory): An initial environmental analysis was carried out to identify the environmental aspects associated with the materials used, the processes taking place in the organization, and the medical services performed at that time. The environmental aspects associated with the activities carried out under normal activity conditions, abnormal operating conditions (maintenance, cleaning, washing, maintenance), as well as emergency situations (accidents) were identified; 3 (good): The degree of significance of the impact generated by the identified environmental aspects was evaluated and those with significant impact were highlighted; 4 (very good): The list of environmental aspects identified as having a significant impact was the basis of the process of identifying the objectives and developing the management program; 5 (excellent): The identified environmental aspects that can generate emergency situations form the basis of emergency plans and the response capacity.

The next objective of the experimental research was to practically validate the theoretical model by implementing the Healthcare-Sustainability innovative framework in the orthopedics department at the County Emergency Clinical Hospital of Targu Mures (CECHTM) [103] and self-evaluation of environmental sustainability. The secondary objective of the experimental research was to test the indicator content and related evaluation

grids in an innovative format that involved evaluating the coupled degrees of importance and achievement.

Following the sequence of indicators (Tables A1–A16) described in the environmental responsibility continuous improvement cycle from Figure 3, the environmental sustainability was evaluated. It was employed in the planning phase with indicators PA4 (environmental impact plan) and PB4 (environmental criteria for selection of materials used in interventions). Then, in the implementation phase, we used indicators IA41 (usage of recycled materials), IA42 (waste recycling), and IB4 (environmentally friendly transfer interventions). The evaluation phase included indicator EA4 (improvement of environmental consumption). The last review phase employed indicators RA4 (mechanisms for monitoring energy consumption and waste generation) and RB4 (environmental measures).

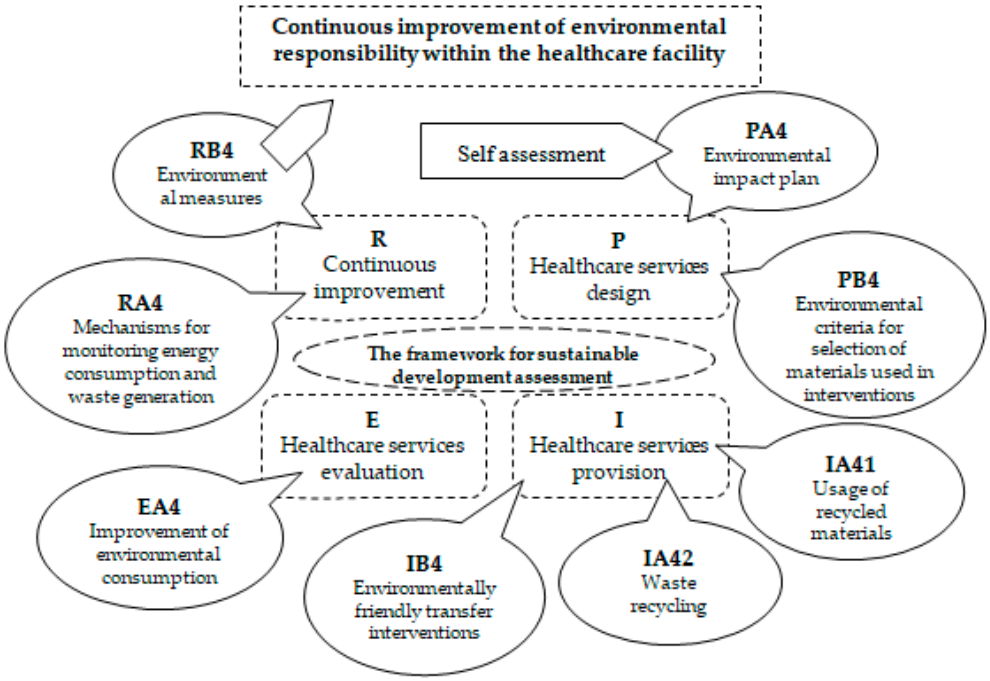


Figure 3. The environmental responsibility continuous improvement cycle: P—plan; I—implement; E—evaluate; R—review.

3. Results

Based on the successful medical practices collected from the scientific literature and presented in Section 2.2, we designed the matrix of indicators of the new H-S innovative framework (Table 2), which had the eight core medical activities of the basic quality cycle in rows and the seven basic topics of social responsibility in columns. When we identified a successful medical practice that connected a core medical activity in the basic quality cycle and a basic subject of social responsibility, we established the need to develop an indicator. We assigned the indicators suggestive names to reflect the links between the two components.

Table 2. The H-S framework indicator matrix.

Social Responsibility Quality Cycle		**1—Organizational Governance**	**2—Human Rights**	**3—Labor Practices**	**4—Environment**	**5—Fair Healthcare Practices**	**6—Patient Issues**	**7—Community Involvement and Development**
(P) Healthcare service design	PA—Healthcare service accreditation	PA1—Decision structures and processes	PA21—Healthcare service accessibility PA22—Medical care services for disadvantaged groups	PA3—Promotion of change and professional development	PA4—Environmental impact plan	PA5—Attitudes of profession towards accreditation	PA6—Performance information	PA7—Community involvement activities
	PB—Patient-centered care intervention design	PB1—Quality assurance process design	PB2—Interventions with positive effects on patient satisfaction	PB3—Quality assurance of patient-centered medical interventions	PB4—Environmental criteria for selection of materials used in interventions	PB5—Effective intervention implementation	PB6—Patient self-care design and self-management	PB7—Content of the interventions adapted to the community
(I) Healthcare service provision	IA—Healthcare service provision	IA1—Computerized support systems for clinical decisions	IA2—Specific medical approaches	I.A31—Continuous healthcare education IA32—Practice guideline implementation and dissemination	IA41—Usage of recycled materials IA42—Waste recycling	IA5—Promotion of patient safety culture	IA6—Critical features for improving the surveillance of patients with chronic conditions	IA71—Networking and partnership IA72—Involvement of volunteers and training networks
	IB—Transfer assurance	IB1—Transfer evaluation mechanisms	IB2—Fair transfer interventions	IB3—Interventions for transfer improvement	IB4—Environmentally friendly transfer interventions	IB5—Features that affect transfer effectiveness	IB6—Interventions to reduce problems with outpatients	IB7—Involvement and participation of professional associations
(E) Healthcare service evaluation	EA—Evaluation and involvement of local opinion leaders	EA1—Existence and recognition of local opinion leaders	EA2—Evaluation of current medical practices	EA3—Professional practices improvement	EA4—Improvement of environmental consumption	EA5—Effective work practices	EA6—Patient-specific issue management	EA7—Local opinion leaders involved in the community
	EB—Satisfaction assessment	EB1—Monitoring mechanism assignment	EB2—Patient satisfaction degree	EB3—Medical staff satisfaction	Not relevant	Not relevant	EB6—Patient satisfaction degree regarding therapeutic benefits	EB7—Satisfaction regarding partnerships
(R) Continuous improvement	RA—Self-assessment	RA1—Self-assessment tools	RA2—Freedom of expression assurance	RA3—Audit and feedback	RA4—Mechanisms for monitoring energy consumption and waste generation	RA5—Feedback to medical staff	RA6—Complaint management	RA7—Communitarian initiatives
	RB—Healthcare service innovation	RB1—Changes to healthcare services	Not relevant	RB3—Medical organization supported by Six Sigma and Lean	RB4—Environmental measures	RB5—Safety checklists	RB6—Incident report	RB7—Educational visits

When we identified several activities for the same connection in the medical practices collected from the scientific literature, we chose to design two indicators. For example, indicators IA41 (usage of recycled materials) and IA42 (waste recycling) were designed to illustrate the connection between the activity IA (healthcare service provision) and the core subject 4 of social responsibility (environment), respectively.

When no successful activity was discovered in the scientific literature, we did not design an indicator. This was the case of the link between activity EB (satisfaction assessment) and core subject 4 (environment). In this way, the H-S matrix was obtained, which comprised 57 indicators, of which 8 indicators described the environmental sustainability [23].

In previous papers [23,104], a matrix of indicators was presented followed by a detailing of the indicator content, evaluation method, and results regarding practical implementation for two of the seven areas of social responsibility: human rights and labor practices (see columns 2 and 3 in Table 2). In this paper, we studied the environmental area of social responsibility, the indicators of which are presented in column 4 of Table 2. The findings obtained from evaluating the indicators that described the environmental sustainability of an emergency hospital are presented below.

PA4 (environmental impact plan): The connection between the orthopedics department at CECHTM as a health unit and the environment was not clear at first glance. Like any other institution, it was concluded that the organization must make daily decisions with an impact on the environment. Environmental analyses are carried out in which aspects related to the used materials are identified. With the support of appropriate tools, a reunified disaster intervention plan was developed, which was organized based on the space, stuff, staff, and systems structure. It also took into account biological hazards. A group with ecological responsibilities is active in the operating room, but the environmental aspects with significant impact are not highlighted.

PB4 (environmental criteria for selection of materials used in interventions): The vision that operating rooms adopt more eco-friendly operating strategies is very current. Inhalational anesthesia is recommended and intravenous sevoflurane and propofol are preferred. Residual anesthetic gas capture systems are used.

The goal of a digitized medical office is a priority. Paperless and film-free digital communication saves time, money, and space, with electronic documents and information more easily shared between different hospital departments. This minimizes damage to the environment. It has been observed that the use of personal computers in offices has increased the consumption of paper because it has facilitated the printing of documents in multiple copies, even if unnecessary.

IA41 (usage of recycled materials): The main issue is reducing the use of single-use surgical materials, such as drapes, gowns, basins, gloves, sponges, and laryngeal masks, and replacing them with reusable products. For these categories of products, the washing and sterilization operations that impact the environment must be evaluated. Cold rather than hot techniques are recommended because they produce less waste and have lower costs.

Another issue that will be discussed with suppliers is the possibility of returning used products that are suitable for recycling, such as plaster splints, synthetic resin splints, etc. Also, the use of plastic/recycled paper garbage bags, recycled paper for printing and copying, packaging materials, boxes, etc. should be generalized.

IA42 (waste recycling): The first step is the separation and management of waste, ensuring recycling and the circular economy. Reprocessing and reuse of external fixators, razors, blades, burs, and tourniquets is advisable in the orthopedic operating room [105]. Infectious medical waste is treated on site. For other categories of waste, thermal disinfection is used with the support of sterilizers. The method of centralized disposal of medical waste through thermal processing of the collected material is not applied. The collection of CECHTM's hazardous medical waste is carried out by specialized companies and it is subsequently treated.

Reusing paper is proposed and waste separation is made easier by providing bins with multiple sections for different categories. Waste management and recycling is demonstrated by reusing boxes, packaging materials, printing and copying materials; recycling furniture/lighting fixtures; avoiding the use of single-use packaging and tableware, small packages of butter, bags of milk, etc.; and using garbage bags made of recycled paper.

IB4 (environmentally friendly transfer interventions): Using electronic communication as an alternative to face-to-face meetings can reduce environmental impact. Environmentally friendly transfer interventions are promoted. Holistic transportation will be promoted by avoiding unnecessary travel and using various remote meeting systems on the internet, leveraging own technological expertise to develop new telemedicine modalities, and promoting and developing car-sharing practices.

Transitional patient care is managed only by nurses. Communication between the emergency department and primary care area is limited. Critical patient transfer devices require interventions by medical personnel. Although electronic medical records are used, the documentation of the transfer center is not accessible in real time. Prior to patient transport, the referring center's clinical documentation must be available. Cross-talk is accessible but its utilization is limited.

EA4 (improvement of environmental consumption): In terms of consumption of raw materials, the main issues are using reusable drapes and surgical linens and establishing recycling programs for paper and cardboard.

Energy consumption in the operating rooms and water consumption are constantly monitored, and the hospital is working to gradually reduce usage. One solution is investing in modern devices and equipment with low energy consumption. Acquiring high-performance modern medical equipment will ensure a sustained rate of modernization of the hospital, continuous improvement of the medical act, increased patient satisfaction, and reduce costs for the services provided. Environmental courses are planned for health personnel to raise their awareness.

Sustainable consumption is also pursued by providing food for hospitalized patients and kiosks on the premises with fair trade products and locally made and grown products and fruit. This reflects the idea of integrating environmental concerns into hospital decision-making under the term "green business."

RA4 (mechanisms for monitoring energy consumption and waste generation): The starting point is the reduction of carbon emissions, the amount of waste in landfills, and energy usage. It was appreciated that energy efficiency is probably the most important aspect to be pursued at CECHTM. It was analyzed that the infrastructure and hospital locations should be optimized in terms of heating, water consumption, power supply, as well as "energy education," which would train staff and patients how to save energy through the use of energy saving signs (for example, turn off the lights when leaving the office, avoid standby, etc.). The installation of fluorescent lamps, control of lighting in rooms with low traffic through the installation of detectors, and signs for turning off the lights are preferred.

CECHTM is also working to reduce electricity consumption by using energy-efficient medical equipment and increasing the efficiency of sterilizers by rotating idle ones and reducing the number of light loads. When purchasing medical equipment, as well as ancillary equipment for medical offices (e.g., computers, refrigerators), attention is paid to the energy consumption of devices and energy savings potential. It has been recognized that while it is possible to be energy efficient, it is more complicated to promote green energy. For this reason, it is recommended that CECHTM look for suppliers that offer green energy equipment.

RB4 (environmental measures): In terms of water pollution, chemicals are considered by reducing the use of environmentally hazardous products and the risks posed by chemicals are written in plain text in a list. Good laboratory safety and chemical management is ensured to reduce the risks of environmental and human health contamination. Non-chemical cleaning methods are used where possible.

In terms of soil management and pollution, the use of environmentally friendly and locally sourced products is promoted and encouraged. Relevant environmental requirements are communicated to suppliers to reduce their environmental impact and encourage suppliers to improve their practices. Suppliers are informed about CECHTM's environmental requirements through a written and posted environmental policy, and they are requested to certify delivered products. Waste is carefully segregated, but the radioactivity concentration level in the hospital's wastewater is not monitored. In the orthopedics department, environmental factors are monitored by means of four sensors placed in the outpatient examination room, the plastering room, the operating room, and the ward.

CECHTM purchases materials and products that cause as little damage to the environment as possible and are preferably eco-labeled, with the European eco-label being preferred first and foremost. All printed materials that are produced externally need to be eco-labeled and provided by an environmentally friendly printing process. The use of small rechargeable batteries is preferred. Regarding air pollution and greenhouse gases, efforts are focused on issues related to medicine, e-health, and transport. Hospital management aims to implement these methods via communication, contact activities, and in-person meetings.

The self-assessment tool in Table 3 depicts the values given to the indicators that describe the environmental sustainability of the organization.

Table 3. Self-assessment tool for environmental sustainability.

No.	Indicator Descriptive	Importance [Ii]	Achievement [Ai]	Sustainability Indicator [Si = Ii × Ai]
1	PA4—Environmental impact plan	5	2	10
2	PB4—Environmental criteria for selection of materials used in interventions	3	3	9
3	IA41—Usage of recycled materials	4	2	8
4	IA42—Waste recycling	4	4	16
5	IB4—Environmentally friendly transfer interventions	3	3	9
6	EA4—Improvement of environmental consumption	4	3	12
7	RA4—Mechanisms for monitoring energy consumption and waste generation	3	4	12
8	RB4—Environmental measures	2	2	4

In Figure 4, the degree of indicator achievement related to environmental sustainability is represented on a scale from 1 to 5.

Indicators PA4 (environmental impact plan), IA41 (usage of recycled materials), and RB4 (environmental measures) had an achievement degree of 2, the lowest in this group, whilst the highest degree of achievement, 4, was registered with indicators IA42 (waste recycling) and RA4 (mechanisms for monitoring energy consumption and waste generation).

The environmental sustainability evaluation graph in Figure 5 depicts the obtained results for the environmental sustainability performance indicators as a correlation between the degrees of importance and achievement.

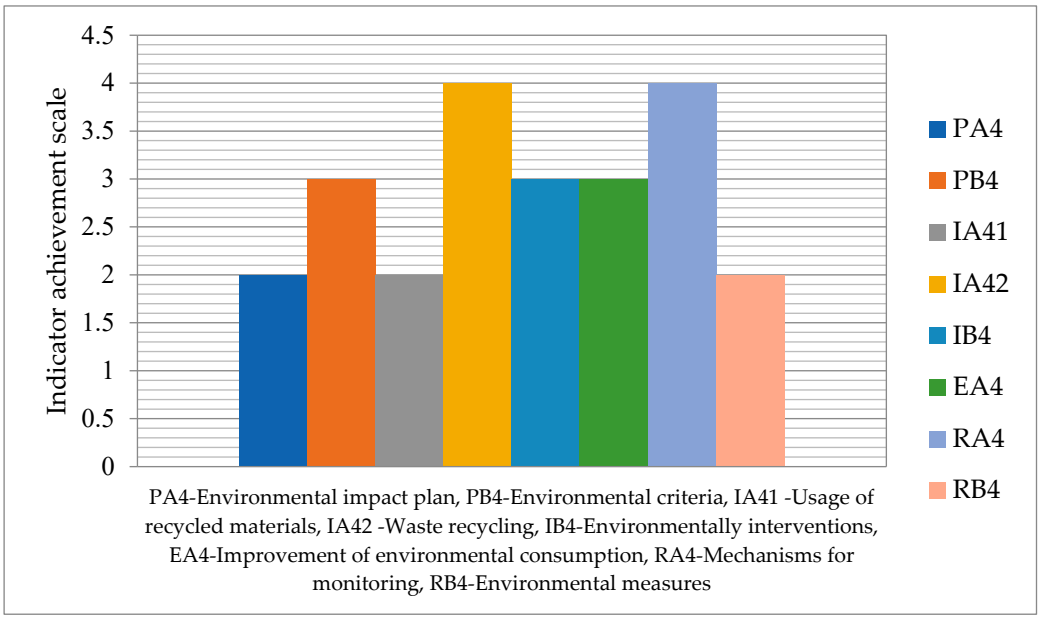
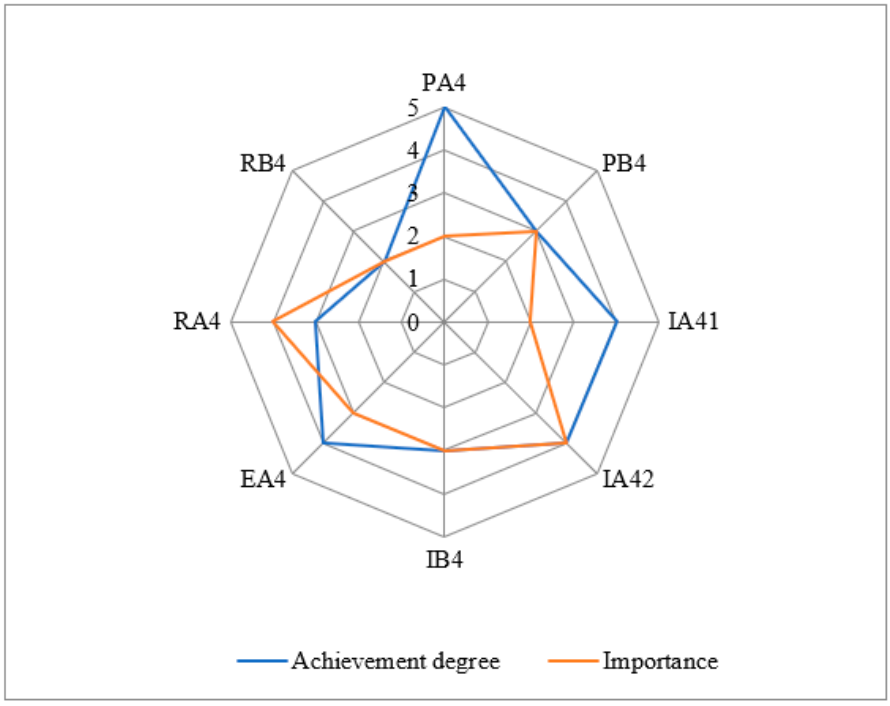


Figure 4. Degree of achievement for environmental sustainability indicators.



PA4—Environmental impact plan

PB4—Environmental criteria for selection of materials used in interventions

IA41—Usage of recycled materials

IA42—Waste recycling

IB4—Environmentally friendly transfer interventions

EA4—Improvement of environmental consumption

RA4—Mechanisms for monitoring energy consumption and waste generation

RB4—Environmental measures

Figure 5. Environmental sustainability evaluation graph.

The global sustainability indicator for environmental sustainability (GS_{ENV}) was calculated as the sum of the values of the eight sustainability indicators presented in Table 3:

$$GS_{ENV} = \sum_{i=1}^{8} S_i = \sum_{i=1}^{8} I_i \cdot A_i = 82 \quad (1)$$

The maximum achievement score for every indicator allowed the maximal value of the global sustainability indicator for environmental sustainability ($GSmax_{ENV}$) to be calculated:

$$GSmax_{ENV} = 5 \cdot \sum_{i=1}^{8} I_i = 5 \cdot 28 = 140 \quad (2)$$

It this way, the overall environmental sustainability level (LGS_{ENV}) was calculated, which represented the percentage of the current value of the indicator in relation to the maximum value it can register:

$$LGS_{ENV} = \frac{GS_{ENV}}{GSmax_{ENV}} \cdot 100 = \frac{82}{140} \cdot 100 = 58.57\% \quad (3)$$

The percentage value indicated by this indicator characterized the degree of fulfillment of the hospital's environmental requirements in relation to the new innovative framework used for evaluation.

In order to develop a plan of measures with well-defined priorities that will lead to improvement of the quality and sustainability assurance system, we developed the environmental sustainability assessment diagram shown in Figure 6.

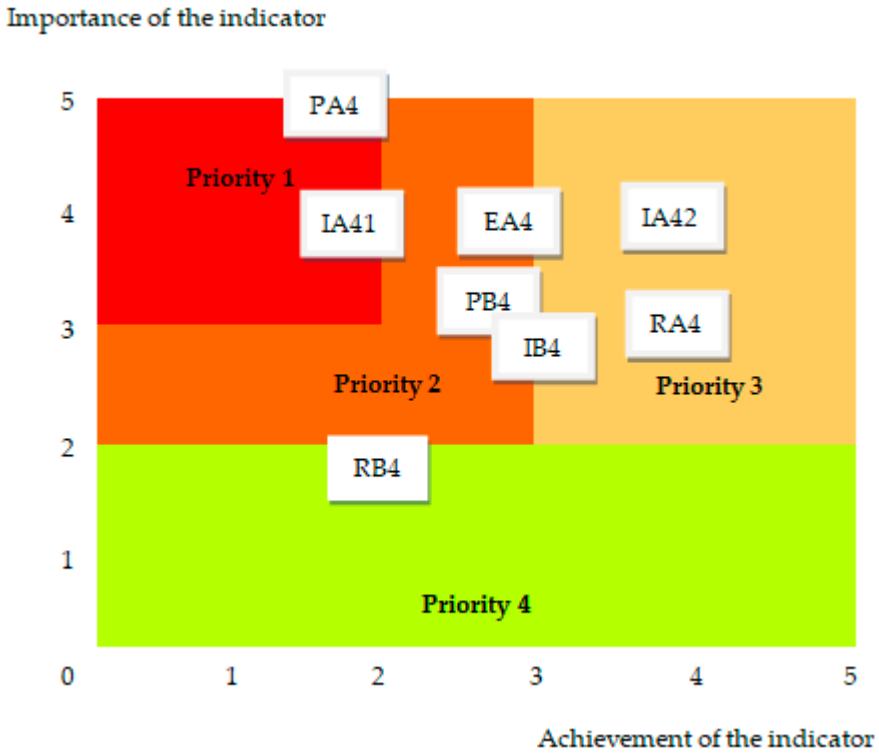


Figure 6. Environmental sustainability assessment diagram.

By using the assessment diagram, priority decisions can be made for the actions formulated for improvement, as the indicators to which they refer are decreasingly located in areas marked by high priority (1) to low priority (4).

In the current situation, as can be seen from Figure 6, indicators PA4 (environmental impact plan) and IA41 (usage of recycled materials) must be given maximum priority in order to improve environmental sustainability.

4. Discussion

Validation in practice of the new H-S innovative framework was performed at the emergency hospital, CECHTM. The team was composed of four evaluators with different responsibilities, including the head of the orthopedics department, an orthopedic resident doctor, the staff member responsible for quality assurance, and the chief medical assistant. The evaluation lasted for one week between 24 and 28 April 2023. The methodology and evaluation results are a good practical example for all interested users.

At the end of the evaluation, we concluded that internal communication with the audited persons and departments was important in order to stimulate and motivate their participation. The evaluation planning activity could be affected by the auditees' lack of time due to current professional concerns. The project manager must be a person with authority who can facilitate the collection of objective evaluations.

Regarding the content of the indicators, the general opinion was that they were adequate for evaluating the environmental sustainability of the hospital. The indicators were in accordance with the most advanced international medical practices from which they were inspired and designed. However, some corrections of indicator descriptions and evaluation questions were necessary by adapting them to the specifics of the organization.

For these reasons, it is advisable that in the future, before starting a new evaluation, the team of evaluators should specify the content of the indicators for the inspected healthcare facility. This will facilitate an objective evaluation of the degree of indicator fulfillment, both in the current and following evaluations. In this way, subjective assessments regarding the degree of fulfillment of the indicators will be avoided and the progress of the hospital in terms of meeting environmental and sustainable development requirements can be easily quantified. The development of a glossary of terms would enable a better mutual understanding of the notions, which were not used in the current activity of the evaluators. Also, the obtained results demonstrated that through the numerical and qualitative evaluation of the H-S framework indicators, with the support of the self-assessment tool, the current state of the organization's sustainability could be determined. Through this new evaluation, the accomplished progress can be tracked. This confirmed our assumption regarding the orientation of the organization, staff, and patients towards environmental sustainability.

Overall, the pilot implementation of the H-S framework constituted an opportunity to improve the environmental culture within the hospital by promoting sustainable and responsible behaviors of the medical staff. The participants in the evaluation appreciated that they had the opportunity to analyze aspects that are not currently addressed in the hospital. With the support of the innovative framework, medical processes were analyzed from a much more complex perspective, which contributed to the sustainable development of the hospital. The results obtained following implementation of the H-S innovative framework at CECHTM demonstrated that it is adequate and comprehensive for evaluating the environmental sustainability of health organizations. Its indicators meet the requirements for orienting medical and organizational practices towards achieving process performance.

The evaluators' participation in this implementation test of the new framework's environmental component was considered to be a success as it satisfied all participants. It was assessed that the developed model of the innovative framework and its indicators were compatible with the European DUQuE hospital quality assessment framework [22] and national hospital accreditation legislation [20]. Compared to these, the added value of the new H-S framework is its objective to promote environmental sustainability and sustainable development in general.

The evaluation results revealed that indicators PA4 (environmental impact plan) and IA41 (usage of recycled materials) must be treated with priority. This requires new

environmental impact evaluations of medical activities, the development of appropriate management plans and recycling procedures, as well as the provision of recycled materials. The results of this research are in agreement with those reported in previous studies of professional training organizations [106–108]. The formats of the frameworks, in terms of defining and evaluating indicators from two fields of healthcare (vocational education and training, respectively), show some similarities but have different contents, which confirms the applicability of the research methodology and its results in different fields of scientific research.

Unlike other frameworks that have been developed for specific contexts, such as that developed by Molero et al. [15] for clinical laboratories, in this research we proposed an innovative framework that can be used by any health facility, regardless of profile, size, or form of ownership. The innovative framework developed in this research covers all aspects related to environmental sustainability, unlike other studies such as that by Savoldelli et al. [9], which only indicated primary aspects such as telemedicine that could make medicine more eco-friendly.

The findings in this paper are also innovative from a methodological point of view. Unlike the research carried out by Malone et al. [10], in which the domains of the framework were developed based on specialists' opinions, the H-S framework was designed based on successful validated practices collected from hospitals around the world.

We showed that although environmental impact assessments are carried out both at institutional and national public healthcare system levels, the results are not used to make decisions that orient hospitals towards sustainability. This finding is in accordance with the research carried out by McGain and Naylor [24]. Operating rooms adopt environmentally friendly strategies by using inhalational anesthesia and residual anesthetic gas capture systems, but unlike the results reported by Sherman et al. [42], less environmentally damaging technologies such as total i.v. anesthesia, neuraxial, or peripheral nerve blocks are not used on a large scale. The leadership role of eco-minded anesthetists in the operating room is restricted and does not confirm the findings of the study by McGain et al. [51].

Contrary to Overcash [45], who claimed that reusable surgical gowns and drapes offer important improvements in durability, we found that they are preferred over disposable surgical materials in medical practice. Hazardous medical waste is collected by specialized companies that treat it without using on-site incineration, as noted in Burd's study [60]. In agreement with the study by Phoon et al. [83], we found a low degree of recycling of orthopedic surgery-related waste, especially for large joint arthroplasties.

Environmentally friendly transfer interventions must continue the digitization effort through cross-talk communication and the use of critical patient transfer devices that do not require medical personnel interventions, as reported by Sun et al. [68].

In our study, we showed that although medical equipment and modern high-performance medical equipment that are recently purchased have low electricity usage, they still contribute substantially to the hospital's energy consumption, as Abraham and Reddy also pointed out [63]. Unlike other hospitals investigated by Álvaro-Meca et al. [92], environmental factors at CECHTM are not monitored in all departments and do not allow for investigation of the increased number of hospitalizations due to respiratory infections.

This study has some limitations. The newly created framework and its indicators do not fully cover all the requirements of healthcare facilities, which may have different forms of organization, medical specializations, sizes, or forms of ownership. It offers managers of healthcare organizations an overview of environmental sustainability aspects, which can be customized according to preference. Another limitation of the study is derived from the validation of the new framework in an emergency hospital with an orthopedic profile. By testing the indicators in other healthcare facilities with different medical profiles, the indicators can be completed and refined so that they respond to a range of medical concerns as diverse as possible. From this perspective, future research must pursue the expansion of indicator content. They should respond to the diversified requirements of the healthcare field. For example, the input elements for the design of indicator RB4

(environmental measures) specified that there is a correlation between hospital admissions of young patients with acute lower respiratory tract infections and exposure to polluted air. Consequently, environmental factors are fundamental determinants of health and can lead to disease and health disparities when the places where people live and work are burdened with social inequities. From this perspective, the research can be continued with the development of an indicator related to environmental health equity. Another research direction is the development of an evaluation methodology that allows training of the evaluators. Digitization of the evaluation process is desirable with the support of a software tool that is easy to install and use.

5. Conclusions

In this study, we developed a new innovative Health-Sustainability (H-S) framework for evaluating and promoting the environmental sustainability of healthcare facilities. The content and evaluation grids of the indicators for environmental sustainability evaluation are presented in detail. The design of the indicators was achieved by collecting the most advanced practices of representative healthcare facilities from all over the world, which were confirmed by clinical studies in recent research. The evaluation grids of the indicators were elaborated in an innovative format comprising the coupled degrees of importance and-achievement of the indicators. This format facilitated the establishment of performance levels for evaluating the environmental sustainability of healthcare facilities.

The compatibility of the H-S framework with the DUQuE European quality framework for hospitals and national hospital accreditation legislation ensures easy and complementary implementation of the hospital's reference systems. Its added value is the main objective of promoting environmental sustainability. The institutions that implement it, the medical staff employed in these structures, and the patients who attend them will be oriented towards environmental sustainability.

Author Contributions: Conceptualization and methodology, F.M. and L.M.; investigation, validation, and resources, F.M.; formal analysis, T.B.; data curation and writing—original draft preparation, F.M.; visualization and writing—review and editing, L.M.; supervision and project administration, T.B. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was approved by the County Emergency Clinical Hospital of Targu Mures Ethics Committee (protocol code Ad.22522/17.09.2021).

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study can be requested from the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. The indicator PA4—environmental impact plan.

Indicator	PA4—Environmental Impact Plan
Description	Environmental impact reduction schemes that are developed in relation to the scope.

Table A1. *Cont.*

Indicator	PA4—Environmental Impact Plan
Evaluation question	Are you aware of the impact of your healthcare activities on the environment (atmosphere/soil/water)? Are the activities carried out polluting the atmosphere and/or soil and/or water? Are there greenhouse gases emitted into the atmosphere? Is the impact of waste on the environment known? How are they considered and what actions are set? Is there concern in the organization regarding the environmental impact on water, or are these effects taken into account? If so, how? What treatment is applied to organic waste? What treatment is applied to inorganic waste? What treatment is applied to toxic waste?

Table A2. Scale for indicator PA4—environmental impact plan.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	The impact of own healthcare activities on the environment (atmosphere/soil/water) is estimated, but no initial environmental analysis is carried out.
2	Satisfactory	An initial environmental analysis is carried out to identify the environmental aspects associated with the materials used, the processes taking place in the organization, and the medical services performed at that time. The environmental aspects associated with the activities carried out under normal activity conditions, abnormal operating conditions (maintenance, cleaning, washing, maintenance), as well as in emergency situations (accidents) are identified.
3	Good	The degree of significance of the impact generated by the identified environmental aspect is evaluated and environmental aspects with significant impact are highlighted.
4	Very good	The list of environmental aspects identified as having a significant impact is the basis of the process for identifying the objectives and developing the management program.
5	Excellent	The identified environmental aspects that can generate emergency situations form the basis of emergency plans and the response capacity.

Table A3. The indicator PB4—environmental criteria for selection of materials used in interventions.

Indicator	PB4—Environmental Criteria for Selection of Materials Used in Interventions
Description	Selection of materials used during patient-centered medical care interventions according to environmental impact.
Evaluation questions	How are the materials to be used in interventions selected? Are specifications consulted if there is any reference to environmental information?

Table A4. Scale for indicator PB4—environmental criteria for selection of materials used in interventions.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	There are no documents, materials, or resources related to this topic. Training materials, self-study, or environmental information resources are not available (not easy to obtain). They could be obtained from certain resource centers.
2	Satisfactory	The healthcare facility has identified existing and accessible resources regarding environmental protection (books, press releases, specific learning materials). Awareness-building resources are available. Within the healthcare facility there are structures/responsibilities that identify new resources available in the market. These are available in resource centers.
3	Good	The materials used in patient-centered medical care interventions take into account environmental protection and eco-friendly behavior. Inhalational anesthesia is recommended and intravenous sevoflurane and propofol are preferred. Documentation resources that are dedicated to the development of environmental awareness are recommended for medical personnel. The organization offers study resources on this topic.
4	Very good	Criteria or indicators that deal with how environmental protection is taken into account allow and facilitate the review of materials used in medical interventions. Criteria may relate to energy efficiency, green building design, alternative energy sources, low carbon transport, local food, waste reduction, and water conservation. Residual anesthetic gas capture systems are used. Documentation resources for awareness are re-ordered for medical staff and easily accessible to all staff. The organization's policy regarding the design and production of materials used in interventions is defined and implemented in partnership with institutions working in the field of sustainability.
5	Excellent	The policy on the supply of materials used in patient-centered healthcare interventions systematically considers environmental protection issues as well as their content and accessibility. During the supply process of materials used in medical care interventions, the healthcare facility checks whether the material is produced in accordance with the environmental protection compliance policy. Materials used in the interventions are supplied in compliance with the criteria regarding environmental protection. The design policy of medical care interventions takes into account the protection of the environment and is implemented together with networks that work in the field of environmental protection at the municipal level, associations, non-profit organizations, and local or national institutions.

Table A5. The indicator IA41—usage of recycled materials.

Indicator	IA41—Usage of Recycled Materials
Description	Recycled materials have priority in use.
Evaluation questions	Are the activities that produce the largest amount of waste known? What recycled materials are used in healthcare services? Are the used materials recycled? Are there resource reuse practices within the organization?

Table A6. Scale for indicator IA41—usage of recycled materials.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	There are no concerns or management related to recycled materials. Knowledge about raw materials and recycling possibilities is very limited.
2	Satisfactory	The quantity of recycled materials (reusable surgical gowns, drapes, laryngeal masks) used in the activities of the healthcare facility is quantified in relation to the volume of training activities for interventions.
3	Good	Various actions are taken to increase the consumption of recycled materials. The organization's staff is made aware of the use of recycled materials.
4	Very good	An action plan aimed at increasing the consumption of recycled materials is established (operating procedures ensure that reusable gowns/surgical drapes/laryngeal/masks/etc. are not discarded prematurely). Some materials are derived from recycling. Recyclable raw materials are used.
5	Excellent	The consumption of materials continuously decreases as the same volume of materials used in the interventions. Raw materials are derived from recycling. Recyclable materials are preferred when making a selection.

Table A7. The indicator IA42—waste recycling.

Indicator	IA42—Waste Recycling
Description	Information about waste recycling within the healthcare facility.
Evaluation questions	What measures or methods are adopted to reduce the amount of waste and organize its selection? What can be done for staff and patient awareness?

Table A8. Scale for indicator IA42—waste recycling.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	The categories of waste generated within the organization are identified: organic, inorganic, toxic.
2	Satisfactory	The impact of generated waste on the environment is known. The effects of one's own activities on the environment are known. Waste is collected selectively and transported centrally at the organization level.
3	Good	The organization's staff and patients are made aware of how waste is collected, the possibilities of recirculation, and the environmental impact they generate.
4	Very good	Toxic waste treatment measures are applied. There are agreements with companies specialized in the transport and treatment of waste. There are agreements with specialized companies for the collection, transport, and disposal of hazardous medical waste (laboratory mixtures, obsolete or unknown chemicals).
5	Excellent	Sustained actions are planned and carried out to reduce the environmental impact through a high degree of waste recycling, within the organization and through collaboration with economic agents authorized to collect and treat waste.

Table A9. The indicator IB4—environmentally friendly transfer interventions.

Indicator	IB4—Environmentally Friendly Transfer Interventions
Description	The existence of transfer interventions, which are more efficient for the environment.
Evaluation questions	Does the organization have transfer interventions that are more effective for the environment? For example, the use of electronic documentation accompanying the transfer, is the energy consumption involved evaluated?

Table A10. Scale for indicator IB4—environmentally friendly transfer interventions.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	There is no knowledge about the environmental impact of the transfer interventions used.
2	Satisfactory	The means of transfer, the accompanying documents, and their impact on the environment are identified. Electronic medical records are used.
3	Good	Promotion of "eco-friendly" transport, reduced number of trips, the means of intervention, and remote communication (video communication, telediagnosis, etc.). Real-time transfer center documentation is accessible in the electronic medical records.
4	Very good	Contacts are established with other stakeholders in transfer interventions (municipalities, associations, etc.) and a partnership is being developed to promote transport reduction. When designing a transfer intervention, the issue of transport is considered and attempts are made to limit travel. Referring center clinical documentation is available prior to transport. Cross-talk is available and used.
5	Excellent	The healthcare facility works together with stakeholders to reduce the time and transfer modes (participation in information networks, adaptation of the medical service offered, etc.).

Table A11. The indicator EA4—improvement of environmental consumption.

Indicator	EA4—Improvement of Environmental Consumption
Description	Detected aspects of improving environmental consumption through reusable materials, establishing recycling programs, modern equipment with low energy consumption.
Evaluation questions	Is there a list of planned actions aimed at improving environmental consumption? Does applying the programmed actions have the effect of reducing consumption?

Table A12. Scale for indicator EA4—improvement of environmental consumption.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	A list of planned actions aimed at improving environmental consumption is drawn up. A report on environmental protection is drawn up, which includes an environmental analysis that is the basis for the selection of significant environmental aspects.
2	Satisfactory	Based on the planned actions to improve environmental consumption, a program of measures is being developed. The operational control of hazardous substances is ensured in accordance with safety data sheets.
3	Good	Starting from the analysis of the planned actions to improve the environmental consumption of the healthcare facility, objectives are developed regarding the use of cover linen and reusable surgical linen, paper, and cardboard recycling, energy and water consumption.
4	Very good	Department managers establish the specific objectives of the areas for which there are managers in accordance with the general objectives. Investments are made in modern appliances and equipment with low energy consumption. The environmental objectives are included in the environmental management program.
5	Excellent	The purchase of modern high-performance medical equipment and medical equipment ensures a sustained pace of modernization of the hospital. Optimization is achieved by raising the awareness of health personnel and participating in training courses. Sustainable consumption is ensured and the hospital is a "green business."

Table A13. The indicator RA4—mechanisms for monitoring energy consumption and waste generation.

Indicator	RA4—Mechanisms for Monitoring Energy Consumption and Waste Generation
Description	Measurement of energy consumption: natural gas, electricity, fuel. Water consumption measurement. Measuring the amount of waste generated.
Evaluation questions	How is energy consumption tracked and (if necessary) what measures to reduce/optimize consumption are applied? How is water consumption tracked? Is a water conservation program implemented? How is the amount of waste generated measured?

Table A14. Scale for indicator RA4—mechanisms for monitoring energy consumption and waste generation.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	The sources of energy (electricity, gas, fuel, steam) consumed within the organization are identified.
2	Satisfactory	The amount of energy (electricity, gas, fuel, steam) and water consumed within the organization are quantified and distributed by location/activity. The amount of waste generated is measured.
3	Good	Actions are implemented to reduce energy consumption, water consumption, and the amount of waste generated.
4	Very good	Consistent limits are set for energy and water consumption, which are included in an action plan communicated to the healthcare facility staff. Studies and analyses are carried out to optimize energy and water consumption.
5	Excellent	Certification of premises with "low energy consumption" is practiced. The dominant share of energy consumption is represented by renewable energies. Rainwater is collected in tanks and used for cleaning, watering plants inside the building, and for small-scale energy production.

Table A15. The indicator RB4—environmental measures.

Indicator	RB4—Environmental Measures
Description	Environmental factors are quantified and environmental improvement measures are applied.
Evaluation questions	By what methods are environmental factors quantified? What environmental measures are taken to reduce the negative impact of the activity performed on the environment?

Table A16. Scale for indicator RB4—environmental measures.

Score [A]	Achievement	Content
0	Not relevant	-
1	Low	The objective of the organization is to monitor compliance with environmental protection legislation. In this sense, the protection of water, soil, and atmosphere is pursued.
2	Satisfactory	Monitoring of environmental factors and waste management is carried out.
3	Good	The activities intended for environmental protection are supervised according to a plan for inspections and analyses/determinations.
4	Very good	The plan for inspections and analyses/determinations contains the physical and chemical characteristics of the water samples necessary for analysis of the quality of the wastewater as well as samples (if they are requires). The sampling points are marked. The sampling of water and air is carried out in accordance with the provisions of the enforced standards, with the frequency established in the plan for inspections and analyses/determinations.
5	Excellent	The results of the environmental analyses are used to determine the performing areas and highlight the activities that require corrective/preventive actions. The monitoring of environmental performance indicators is a continuous process, tracking the amount of emissions, the number of environmental incidents/accidents, the specific amounts of pollutants, investments in environmental protection, and the number of complaints/lawsuits.

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