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Article

Assessment of Environmental Sustainability in Health Care Organizations

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Abstract: Healthcare organizations should set a standard in corporate social responsibility and encourage environmental sustainability, since protection of the environment implies the development of preventive measures in healthcare. Environmental concern has traditionally focused on manufacturing plants. However, a Health Care Organization (HCO) is the only type of company which generates all existing classes of waste, and 20% is dangerous, being infectious, toxic or radioactive in nature. Despite the extensive literature analysing environmental matters, there is no objective model for assessing the environmental sustainability of HCOs in such a way that the results may be compared over time for an organization, and between different organizations, to give a comparison or benchmarking tool for HCOs. This paper presents a Multi-Criteria Decision Analysis model integrating a Fuzzy Analytic Hierarchy Process and utility theory, to evaluate environmental sustainability in HCOs. The model uses criteria assessed as a function of the number of annual treatments undertaken. The model has been tested in two HCOs of very different sizes.

Keywords: environmental sustainability; health care organizations; multi-criteria techniques

1. Introduction

Health care organizations should encourage economic, social and environmental sustainability, so as to set standards for corporate social responsibility. To achieve this, they should seek a balance between care and economic need, to guarantee sustainable development. Among other things, this implies minimizing environmental impact, since protection of the environment implies the development of preventive measures in healthcare [1].

The literature contains a large number of contributions on environmental issues in different types of manufacturing organizations (see for example the electronics industry [2], extractive industry [3], manufacturing companies [4], power generation plants [5], chemical industry [6], public transport [7], food industry [8], textile industry [9], and in small and medium companies in the surface mining sector [10]. Nevertheless, in the area of health care organizations, the contributions are almost non-existent.

If waste is classified in this way:

- Group I: General, no risk.
- Group II: Sanitary, assimilated to urban.
- Group III: Sanitary, potentially infectious.
- Group IV: Bodies and human remains.
- Group V: Dangerous chemical waste.
- Group VI: Cytotoxic with carcinogenic, mutagenic and teratogenic risk.
- Group VII: Radioactive.

Health Care Organizations (HCOs) are the only businesses that produce all the classes of waste; furthermore, 20% of this waste is dangerous, being infectious, toxic or radioactive in nature [11]. The quantity of dangerous sanitary waste is 6 kg per person per year in developed countries and 0.5 kg in developing countries [12]. However, in these countries dangerous sanitary waste is not generally separated from the harmless, and so the quantity of dangerous waste is in fact much higher.

The inadequate handling of hospital waste can, therefore, create a risk to people, in the spread of infectious diseases, and also for the environment.

Due to the serious implications for the environment, HCOs have, in the last decade in Spain, begun the belated introduction of environmental management into their strategic objectives.

The environmental responsibilities of a HCO can be fulfilled by introducing an Environmental Management System (EMS) in accordance with ISO standard 14001. An EMS is voluntary and allows companies to control the activities of the products and processes that may cause environmental impact, and to minimize the effects of their operations on the environment. To introduce an EMS, a health care organization may use as a starting point, although it is not essential, these standards:

- Eco-Management and Audit Scheme (EMAS) or Regulation (EC) N° 761/2001, which is applied officially in member countries of the European Union.
- Standard ISO 14001:2004. Applied internationally.

These two standards have a similar philosophy although Regulation EMAS is more demanding than Standard ISO 14001.

Nevertheless, only 14% of Spanish healthcare organizations have introduced an EMS, in all cases certifying to ISO Standard 14001; and only 2% of these also have EMAS [12].

As part of these EMSs, a healthcare centre keeps annual sustainability logs, for which it is necessary to define environmental indicators to manage comparable information and permit the development of the environmental behaviour of the HCO over time. However, not all the indicators looked at have the same impact on the environment; some of them may have serious repercussions on people, and the environment, other only a small impact. It is also possible that various indicators are related and the same factor is assessed two or more times. A further consideration is that to be able to be compared over time, indicators must be used that take into account the healthcare activities per period of time.

For environmental assessment in an organization, many socioeconomic, technical, environmental and political aspects must be considered. They may also be different stakeholders and scenarios [13]. These characteristics make the application of Multi-Criteria Decision Analysis (MCDA) very suitable, as it allows acceptable compromise solutions to be found when criteria are in conflict [14]. Also, these techniques allow a large quantity of data, uncertainty, relations and objectives to be handled, which are the typical characteristics of a real-world policy problem [15]. The use of MCDA techniques leads to significant improvement in the decision-making process, and may guarantee acceptance by public opinion or by the managers of an organization of the solution proposed by the multi-criteria model [13]. In addition, it is recognised that MCDA approaches provide the flexibility and robustness to deal with benchmarking problems when multiple variables and units of measurement are used [16]. This has contributed to a considerable increase in literature using MCDA in the environmental field in the last two decades [17].

Other methodologies for environmental assessment such as key performance indicators or the balanced scorecard do not allow an objective modelling of the decision problem. MCDA techniques use one or more group or individual decision-makers to make judgements to obtain a value for the importance of each environmental question for the organization. Furthermore, they can analyse both quantitative and qualitative criteria simultaneously and guarantee no redundancy in the evaluation of items since the criteria considered must be independent. The fuzzy analytic hierarchy process takes account of uncertainty, vagueness or ambiguous situations of the judgements made by the decision makers [18]. The decision makers also prefer to use a linguistic expression rather than a crisp number because it is difficult to give an exact figure in the assessment and evaluation of decision making problems [19]. Additionally, the fuzzy analytic hierarchy process carries over from its predecessor, the Analytic Hierarchy Process (AHP), its capacity to divide a complicated decision, with numerous criteria in conflict, into a hierarchical system of elements, facilitating decision making. The use of pairwise comparisons allows a ratio scale of measurement to be obtained, leading to the generation of more precise information about the preferences of decision makers; for this reason, it is not necessary to define a measurement scale explicitly for each criterion [20]. It also includes a system for evaluating the consistency of judgements made by decision makers [21]. The application of fuzzy AHP may be easily understood by the managers those ultimately responsible for accepting and taking decisions.

Among the literature which applies MCDA techniques and specially fuzzy AHP for environmental sustainability should be highlighted, for example, Gumus [22] which presents a methodology for selection of the most suitable hazardous waste transportation firms. [23] obtains the weights of criteria to establish ex-ante and ex-post stages of renewable energy dissemination programs in Korea. Kaya and Kahraman [24] propose an environmental impact assessment methodology related to urban industrial planning. Reza *et al.* [25] combines morphological analysis and AHP to choose, from the first stage of the development process of a new product, the most sustainable design; the work of Chan *et al.* takes the same approach [26] where green designs are selected by a multi-criteria model built on fuzzy logic and AHP; it incorporates the concepts of life-cycle assessment and environmental management accounting. This model facilitates identifying product design improvement options and reduces the development lead time eliminating undesirable design alternatives. Boran *et al.* [27] uses intuitive fuzzy Techniques for Order of Preference by Similarity to Ideal Solution (TOPSIS) to assess renewable energy technologies for electricity generation, such as solar panels, hydro, wind, and geothermal energy in Turkey. Wang *et al.* [28] constructs a model for selection of green initiatives in the fashion industry. Larimian *et al.* [29] uses a model built on fuzzy group AHP to assess environmental sustainability from the perspective of security in different areas of a region of Tehran. Vinodh *et al.* [30] sets out an evaluation model to determine the best method for recycling plastics. Pourebrahim *et al.* [31] makes a choice among criteria and alternatives for conservation development in a coastal area. Egilmez *et al.* [16] assesses the environmental sustainability of 27 large cities in the US and Canada using fuzzy multi-criteria decision-making. The results show that the average sustainability performance score is found to be 0.524 on a scale from 0 and 1. The metropolis with the highest sustainability performance score is found to be New York with 0.703 and the poorest performing city is identified as Cleveland with 0.394. CO_2 emissions and public transport are found to have the most significant impact on sustainability scores. Simane and Zaitchik [32] use AHP to assess the sustainability of community based adaptation activities in 20 community based organizations of Ethiopia to promote resilience to climate change. The results show that inadequacies in community participation, farming capacity, local government commitment, training of local community members and bureaucratic efficiency are important obstacles to use conservation of natural resources as the primary framework for community based organization activities [33] uses AHP to assess building sustainability such that from the first stages of development of the building projects the requirements for sustainable building are satisfied. Matsuura *et al.* [34] uses AHP and a geographical information system, differences in the spatial characteristics of the habitat distribution of fern species due to natural and anthropogenic factors; this allows the spatial characteristics non-timber forest product harvesting to be defined, and ensures sustainable management practices. [35] describes the use of a sustainability index which allows companies and their respective supply chains to obtain information on the level of economic, social and environmental sustainability; they use AHP in the weighting process for the indicators used in the assessment. Galvez *et al.* [36] propose a model that includes mixed integer linear programming optimization and AHP to evaluate possible scenarios for the implementation of an anaerobic co-digestion logistics network used to create sustainable energy production processes from biogas; this model was used in the design of a municipal biogas facility in France.

Therefore, despite the extensive literature on assessment of environmental sustainability, there is no model that allows environmental sustainability in a healthcare organization to be objectively assessed, and which permits comparison of results over time and between organizations. Carnero [17] represents the only precedent in this field; however, it does not take into account the annual variation in the number of services provided by the HCO, and so the results are not comparable over time within the same organization, and neither are they comparable between HCOs; furthermore, it does not consider certain relevant factors when assessing environmental sustainability, such as CO_2 emissions, the existence of accidents with environmental implications, care of biodiversity in the area of the hospital, *etc.*

It should be borne in mind that monitoring sustainability is fundamental to decision making and management of the activities that comprise an organization's systems and processes [35].

This research describes a model using a multi-criteria approach that can serve as an internal audit of the EMS used by a HCO. It can assess objectively and continuously the performance of actions for environmental improvement. Unlike traditional audits, the model described benefits from the advantages of the use of multi-criteria techniques, as not all the environmental questions have the same importance, and it provides an easy-to-use model for the HCO, with criteria specific to health care, and which allows environmental sustainability to be controlled over time. Multi-criteria approaches also provide the flexibility and robustness to deal with the benchmarking problems when multiple variables and measuring units are used [16].

This paper is intended to contribute to the emerging field of assessment of sustainability and sustainability performance benchmarking with a methodology that incorporates expert judgements with fuzzy multi-criteria techniques [16].

This article is structured as follows. Section 2 describes the multi-criteria model for assessing environmental sustainability in an HCO, including the structure of the model and the weighting process. Section 3 describes two examples of the application of the model to two HCOs of different sizes. Section 4 sets out the conclusions, the following section the acknowledgements, and the article concludes with the references.

2. Multi-Criteria Model for the Assessment of Environmental Sustainability in Health Care Organizations

Fuzzy set theory takes account of the uncertainty, vagueness and ambiguous situations of the judgements of the decision makers [18].

The model described in this research uses fuzzy AHP. The fuzzy versions of AHP are designed to take account of the vagueness of the parameters and decision-makers usually feel more confident giving interval judgments rather than fixed value judgments [18].

A triangular fuzzy number is defined by $\tilde{a} = (l, m, u)$, where l and u are the lower and upper limits respectively and m is the point where the membership function $\mu_{\tilde{a}}(x) = 1$. $\tilde{a}$ is defined by the membership function $\mu_{\tilde{a}}(x): \Re \rightarrow [0,\ 1]$ according to Equation (1) [37],

$$\mu_{\tilde{a}}(x) = \begin{cases} \dfrac{x}{m-l} - \dfrac{l}{m-l}, & x \in [l, m] \\ \dfrac{x}{m-u} - \dfrac{u}{m-u}, & x \in [m, u] \\ 0, & otherwise \end{cases} \tag{1}$$

with $l \le m \le u$; if $l = m = u$ then the fuzzy number becomes a crisp number by convention.

The operational laws of two triangular fuzzy numbers $\tilde{a}_1 = (l_1, m_1, u_1)$ and $\tilde{a}_2 = (l_2, m_2, u_2)$ are the following [38]:

$$\tilde{a}_1 \oplus \tilde{a}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{2}$$

$$\tilde{a}_1 \,\Theta\, \tilde{a}_2 = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \tag{3}$$

$$\tilde{a}_1 \otimes \tilde{a}_2 \approx (l_1 l_2, m_1 m_2, u_1 u_2) \tag{4}$$

$$\tilde{a}_1 \,\Phi\, \tilde{a}_2 \approx \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2}\right) \tag{5}$$

$$\tilde{a}_1^{-1} \approx (\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1})\ for\ l, m, u > 0 \tag{6}$$

$$k \otimes \tilde{a}_1 \approx (kl_1, km_1, ku_1) \quad k > 0, k \in R \tag{7}$$

2.1. Structuring

The criteria have been chosen after analysing many environmental declaration documents published by different HCOs [39–50]. Each criterion is associated with a descriptor that allows an objective measurement to be made. These descriptors have the following characteristics [1]:

- Comparability: The indicators should be comparable and reflect developments in the environmental behaviour of the HCO.
- Balance between problematic (bad) and promising (good) aspects.
- Continuity: The indicators are based on the same criteria and applied to comparable time periods.
- Currency: The indicators should be able to be measured with sufficient frequency that appropriate measure can be taken.
- Clarity: The indicators should be clear and comprehensible.

These criteria further satisfy the following characteristics established by Keeney [51]: They must be exhaustive, concise, non-redundant, made operational with performance descriptors and independent.

The criteria and subcriteria used in the multi-criteria model are:

- Water consumption (WAT) (m^3) [39–49]. Water is a natural resource essential for human activity and socio-economic development, and so control of its consumption is vital, especially in countries with water shortages due to the characteristics of their climate. For HCO it is recommended that consumption be less than the previous year.
- Energy efficiency (ENE) [45,49]. Two areas are assessed:
    (a) Annual consumption (MW/h) of electricity, refrigerating energy, thermal energy and natural gas (POW) [39–48]. The generation and consumption of energy from fossil fuels is a main driver of climate change and contributes to other problems of atmospheric pollution (acidification and ozone pollution of the troposphere, air quality, *etc.*). It is also responsible for the consumption of a large amount of resources. The improvement of insulation, introduction of new, more efficient lighting systems, optimization of natural light conditions in offices, natural ventilation, *etc.* can bring about a significant decrease in consumption.
    (b) Consumption of renewable energy (REN) (MW/h) [39–41,45,50]. The use of renewable energy sources is assessed through the use of photovoltaic solar panels or photothermal panels (for example for warming the water in a hydrotherapy pool).
- Waste production (WAS) [39–41,44,46]. The annual production of waste is assessed. This is divided into subcriteria:
    (a) Group I waste (GROUP I) (10^3 kg) [39–41,48,49]. This is waste assimilated to urban waste, and therefore not requiring special handling; among others it includes: Plastics, paper and cardboard, office, kitchen and catering materials, *etc.*

(b) Group II waste (GROUP II) (10^3 kg) [39–41,48,49]. This is non-specific sanitary waste derived from healthcare activity and which may come from non-contagious patients (not included in group III), and which are bound by additional handling requirements in the centre, while their handling outside the hospital is assimilated to group I waste (for example material from treatments, plaster, fungible fabrics, clothes, *etc.*).

(c) Group III waste (GROUP III) (10^3 kg) [39–41,48,49]. This is specific sanitary waste to which special prevention measures must be applied in handling, collection, storage, transport and destruction, as they may represent a risk to staff and the public. This includes infectious sanitary waste from both humans and animals; it therefore includes pointed and sharp-edged material, blood, blood products, cultures, anatomical remains in formaldehyde, *etc.* It also includes other dangerous waste including industrial oils, batteries, non-halogenated solvents, contaminated containers, liquids used in radiology, out-of-date or rejected medicines, chemical waste and cytostatic waste (cytostatics are medicines which include a series of chemical substances used in radiotherapy, chemotherapy, immunotherapy, hormone therapy or associated with surgery).

This category does not include waste in groups IV and V, as the risk they pose is subject to special legislation which must be obeyed.

- Greenhouse gas emissions (GGE) (quantity of 10^3 kg equivalents of CO_2) [39–41,45,47–49]. Annual emissions of greenhouse gases are measured, primarily CO_2, although the quantity of CH_2 and N_2O emitted while administering medical gases to patients is also assessed.
- Consumption of materials (MAT) (10^3 kg) [39–41,45,49]. Annual consumption of different materials such as fluorescents, glutaraldehyde, computer material, ethylene oxide, paper, batteries, Petri dishes, test tubes, both plastic and glass, xylene, digital thermometers, *etc.*
- Recycling (REC) (10^3 kg) [39–41]. Annual quantity of waste recycled.
- Environmental accidents (ACC) [39–41,49]. The existence of serious environmental accidents is assessed, such as for example the entry of uncontrolled contaminants in the sewage system, spillage of dangerous substances on the floor, leaks or spills of natural gas or petrol, mixture of dangerous substances or loss or disappearance of dangerous waste, spillage or acetylene or refrigerating gas, outbreaks of legionnaires' disease, radiological emissions, leaks of ethylene oxide, fires, floods, *etc.*
- Biodiversity (BIO) [39–41,48–49]. The impact of an HCO on its surroundings is evaluated, that is, adaptation to the rural or forest environment, conservation of species on the endangered species lists of the International Union for Conservation of Nature (IUCN) or species listed in the national inventory of endemic or endangered species of the Spanish Ministry of Agriculture, Food and Environment, and actions carried out for the continuous improvement of the environmental impact of the organization on its surroundings are also assessed.

These criteria and subcriteria are set out in a hierarchy with the objective at the top, then the criteria, and at the bottom the subcriteria. The hierarchy of the multi-criteria model is shown in Figure 1.

A descriptor is associated with each subcriterion. A descriptor is an ordered set of possible impact levels which allows each alternative to be objectively evaluated [52].

All the descriptors defined have been evaluated according to the annual number of treatments provided by the HCO, as the consumption of materials, energy, *etc.* is a function of the level of activity or service. In this way, the results are comparable over time for an HCO, and they are also comparable between HCOs, giving a comparative benchmarking tool. The percentage of change from one year to the next is also measured.

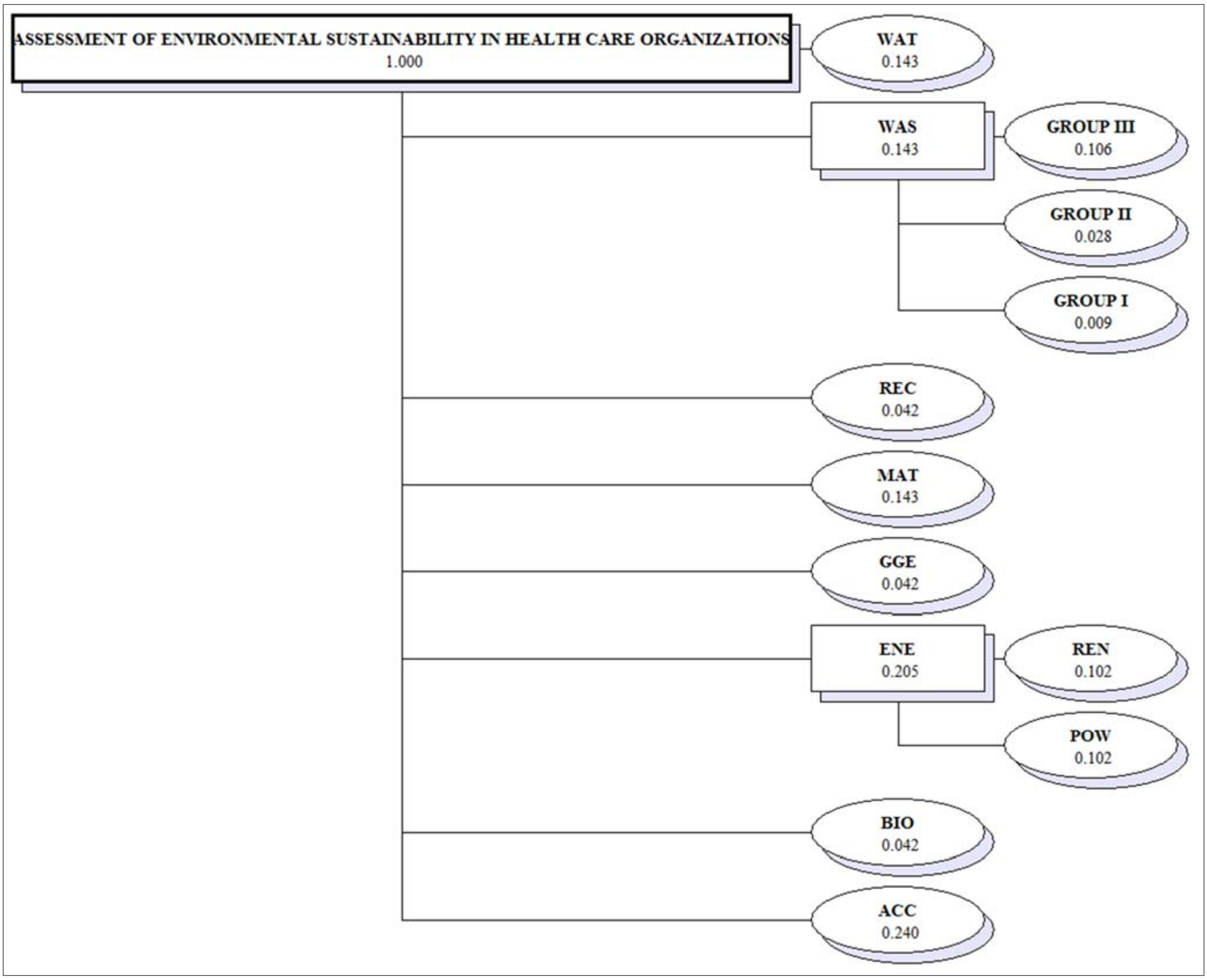

Figure 1. Hierarchy.

For the criteria of environmental accidents and biodiversity, qualitative descriptors have been conceived. This type of descriptor is used when the criterion is subjective in nature or when it includes a set of interrelated elementary concepts. Table 1 shows the descriptor associated with the criterion biodiversity.

As shown in Tejedor [47], there are no indicators, especially designed for the health sector, that are both universally recognised and that provide for an effective comparison between different HCOs. Likewise there are no absolute values recommended for these indicators. Thus, it is felt that the percentage variation with respect to the values obtained by the HCO itself is the most suitable measure, which is in fact the usual practice in HCOs.

Table 1. Scale levels of descriptor associated to criterion biodiversity.

Level of Performance	Scale Levels
L1 (highest level of performance)	There is complete protection of endangered species from the IUCN lists of endemic or endangered species listed by the Spanish Ministry of Agriculture, Food and Environment, or there are no species in these categories in the area affected by the activity of the HCO. The facilities of the HCO are being gradually adapted, in accordance with the ecosystem, to the rural or landscaped environment about it, or the HCO is in an urban environment. Action for continuous improvement of the environmental impact of the HCO is performed periodically (regeneration of autochthonous vegetation in areas next to the facilities, removal of invasive species, *etc.*).
L2	There is complete protection of endangered species from the IUCN lists of endemic or endangered species listed by the Spanish Ministry of Agriculture, Food and Environment, or there are no species in these categories in the area affected by the activity of the HCO. The facilities of the HCO are being gradually adapted, in accordance with the ecosystem, to the rural or forest environment about it, or the HCO is in an urban environment. Actions to improve the environmental impact of the HCO on the environment are carried out.
L3	There is complete protection of endangered species from the IUCN lists of endemic or endangered species listed by the Spanish Ministry of Agriculture, Food and Environment, or there are no species in these categories in the area affected by the activity of the HCO. There is no gradual ecosystemic adaptation of the facilities of the HCO to the rural or landscaped environment. Actions to improve the environmental impact of the HCO are carried out.
L4	There is protection of endangered species from the IUCN lists of endemic or endangered species listed by the Spanish Ministry of Agriculture, Food and Environment, or there are no species in these categories in the area affected by the activity of the HCO. There is no gradual ecosystemic adaptation of the facilities of the HCO to the rural or landscaped environment. There is no action to improve the environmental impact of the organization.
L5 (lowest level of performance)	There is no protection of endangered species from the IUCN lists of endemic or endangered species listed by the Spanish Ministry of Agriculture, Food and Environment. There is no gradual ecosystemic adaptation of the facilities of the HCO to the rural or landscaped environment. There is no action to improve the environmental impact of the organization.

Utility functions [53] have been defined to assess the criteria and/or subcriteria related to consumption or recycling. Given that each criterion and/or subcriterion is assessed with distinct units or scales, the use of utility functions means that all the criteria and/or subcriteria are assessed on a common scale (utility) with a range from 0 to 1. The preferred utility is 1 and the least preferred is 0. It is established that the optimal situation is to show a decrease of 100% with respect to the previous year's consumption. The worst situation is when consumption increases 100% with respect to the consumption of the previous year; both cases are always evaluated with regard to the number of treatments provided by the HCO. For the recycling criterion an increment of 100% with respect to the previous year's value for care services provided annually is considered to be optimal, while a decrease of 100% in this criterion is considered the worst result. The value ±100% was chosen as the best valuation depending on the criterion, because the HCOs analysed consider that a decrease in the consumption of a material of 100% is the aim sought. The utility function constructed for the group III waste production subcriterion is shown in Figure 2.

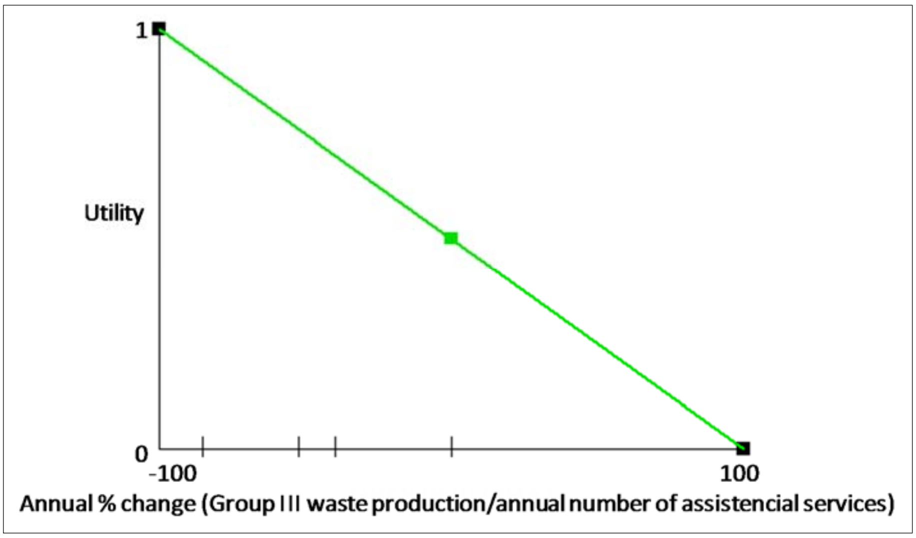

Figure 2. Utility function for group III waste production criterion (GROUP III).

2.2. Weighting

The weightings of the criteria and of the scale levels for each indicator must be obtained from the fuzzy judgements matrix $\tilde{A}$. This matrix has as elements the fuzzy comparison values $\tilde{a}_{ij}$, which express the decision-maker's opinion about the relative importance of element *i* over element *j* at the same level of hierarchy.

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1,1,1) & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & (1,1,1) \end{bmatrix} \quad (8)$$

To perform the pairwise comparisons of $\tilde{A}$, the decision maker uses a fuzzy scale, such as for example that shown in Table 2. This scale was chosen because it corresponds better with the original preference scale of the crisp AHP established by Saaty [54].

Table 2. Fuzzy scale.

Linguistic Scale	Fuzzy Number	Triangular Fuzzy Numbers	Triangular Fuzzy Reciprocal Numbers
Equally important	$\tilde{1}$	$(1,1,1)$	$(1, 1, 1)$
Judgement values between equally and moderately	$\tilde{2}$	$(1,2,3)$	$(1/3, 1/2, 1)$
Moderately more important	$\tilde{3}$	$(2,3,4)$	$(1/4, 1/3, 1/2)$
Judgement values between moderately and strongly	$\tilde{4}$	$(3,4,5)$	$(1/5, 1/4, 1/3)$
Strongly more important	$\tilde{5}$	$(4,5,6)$	$(1/6, 1/5, 1/4)$
Judgement values between strongly and very strongly	$\tilde{6}$	$(5,6,7)$	$(1/7, 1/6, 1/5)$
Very strongly more important	$\tilde{7}$	$(6,7,8)$	$(1/8, 1/7, 1/6)$
Judgement values between very strongly and extremely	$\tilde{8}$	$(7,8,9)$	$(1/9, 1/8, 1/7)$
Extremely more important	$\tilde{9}$	$(8,9,9)$	$(1/9, 1/9, 1/8)$

To obtain a pairwise comparison matrix for the decision criteria and subcriteria, an expert in environmental matters was consulted. The decision maker was asked to evaluate the importance of the criteria and subcriteria applying the fuzzy scale set out in Table 2; the result was the pairwise comparison matrix for the criteria shown in Table 3.

Table 3. The pairwise comparison matrix.

	ACC	**ENE**	**WAS**	**WAT**	**MAT**	**GGE**	**REC**	**BIO**
ACC	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)
ENE	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
WAS	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
WAT	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
MAT	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
GCE	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)
REC	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)
BIO	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)

Next, the value of the fuzzy synthetic extent with respect to the *i*-object $\widetilde{S}_i$ is obtained; this is done by applying Equation (9) [37]:

$$\widetilde{S}_i = \sum_{j=1}^{m} \widetilde{a}_{ij} \otimes [\sum_{i=1}^{n}\sum_{j=1}^{m} \widetilde{a}_{ij}]^{-1} \tag{9}$$

where $\widetilde{a}_{ij}$ is a triangular fuzzy number of the decision matrix $\widetilde{A}$ with n objects and m goals.

$$(\sum_{i=1}^{n}\sum_{j=1}^{m} \widetilde{a}_{g_i}^{j})^{-1} = (\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}}) = (\frac{1}{107.500}, \frac{1}{63.000}, \frac{1}{52.750}) \tag{10}$$

The values of fuzzy synthetic extents obtained are:

$$\tilde{S}_{ACC} = \sum_{j=1}^{m} \tilde{a}_{g_i}^{j} \otimes [\sum_{i=1}^{n}\sum_{j=1}^{m} \tilde{a}_{g_i}^{j}]^{-1} = (\frac{11}{107.500}, \frac{17}{63.000}, \frac{23}{52.750}) = (0.102,\ 0.270,\ 0.436)$$

$$\tilde{S}_{ENE} = (\frac{8}{107.500}, \frac{14}{63.000}, \frac{20}{52.750}) = (0.074,\ 0.222,\ 0.379)$$

$$\tilde{S}_{WAS} = (\frac{6.667}{107.500}, \frac{10}{63.000}, \frac{14}{52.750}) = (0.062,\ 0.159,\ 0.265)$$

$$\tilde{S}_{WAT} = (\frac{6.667}{107.500}, \frac{10}{63.000}, \frac{14}{52.750}) = (0.062,\ 0.159,\ 0.265)$$

$$\tilde{S}_{MAT} = (\frac{6.667}{107.500}, \frac{10}{63.000}, \frac{14}{52.750}) = (0.062,\ 0.159,\ 0.265)$$

$$\tilde{S}_{GGE} = (\frac{4.583}{107.500}, \frac{5.333}{63.000}, \frac{7.500}{52.750}) = (0.043, 0.085, 0.142)$$

$$\tilde{S}_{REC} = (\frac{4.583}{107.500}, \frac{5.333}{63.000}, \frac{7.500}{52.750}) = (0.043, 0.085, 0.142)$$

$$\tilde{S}_{BIO} = (\frac{4.583}{107.500}, \frac{5.333}{63.000}, \frac{7.500}{52.750}) = (0.043, 0.085, 0.142)$$

The values of fuzzy synthetic extents are compared and the degree of possibility of $V(\widetilde{S}_j \geq \widetilde{S}_i)$ is calculated using Equation (11) [19].

$$V(\widetilde{S}_j \geq \widetilde{S}_i) = height(\widetilde{S}_i \cap \widetilde{S}_j) = \begin{cases} 1, & if\ m_j \geq m_i \\ 0, & if\ l_i \geq u_j \\ \dfrac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)}, & otherwise \end{cases} \quad (11)$$

Applying Equation (11) to the data of the evaluation model being developed gives the following results:

$V(\widetilde{S}_{ACC} \geq \widetilde{S}_{ENE}) = 1.000$ because $m_j = 0.270 \geq m_i = 0.222$ and a similar situation occurs for $V(\widetilde{S}_{ACC} \geq \widetilde{S}_{WAS}) = 1.000$, $V(\widetilde{S}_{ACC} \geq \widetilde{S}_{WAT}) = 1.000$, $V(\widetilde{S}_{ACC} \geq \widetilde{S}_{MAT}) = 1.000$, $V(\widetilde{S}_{ACC} \geq \widetilde{S}_{GGE}) = 1.000$, $V(\widetilde{S}_{ACC} \geq \widetilde{S}_{REC}) = 1.000$, $V(\widetilde{S}_{ACC} \geq \widetilde{S}_{BIO}) = 1.000$.

$V(\widetilde{S}_{ENE} \geq \widetilde{S}_{ACC}) = \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} = \dfrac{0.102 - 0.379}{(0.222 - 0.379) - (0.270 - 0.102)} = 0.853$; because $m_j < m_i$,

$V(\widetilde{S}_{ENE} \geq \widetilde{S}_{WAS}) = 1.000$, $V(\widetilde{S}_{ENE} \geq \widetilde{S}_{WAT}) = 1.000$ $V(\widetilde{S}_{ENE} \geq \widetilde{S}_{MAT}) = 1.000$, $V(\widetilde{S}_{ENE} \geq \widetilde{S}_{GGE}) = 1.000$, $V(\widetilde{S}_{ENE} \geq \widetilde{S}_{REC}) = 1.000$, $V(\widetilde{S}_{ENE} \geq \widetilde{S}_{BIO}) = 1.000$.

The remaining values are:

$V(\widetilde{S}_{WAS} \geq \widetilde{S}_{ACC}) = 0.595$, $V(\widetilde{S}_{WAS} \geq \widetilde{S}_{ENE}) = 0.750$, $V(\widetilde{S}_{WAS} \geq \widetilde{S}_{WAT}) = 1.000$ $V(\widetilde{S}_{WAS} \geq \widetilde{S}_{MAT}) = 1.000$, $V(\widetilde{S}_{WAS} \geq \widetilde{S}_{GGE}) = 1.000$, $V(\widetilde{S}_{WAS} \geq \widetilde{S}_{REC}) = 1.000$, $V(\widetilde{S}_{WAS} \geq \widetilde{S}_{BIO}) = 1.000$.

$V(\widetilde{S}_{WAT} \geq \widetilde{S}_{ACC}) = 0.595$, $V(\widetilde{S}_{WAT} \geq \widetilde{S}_{ENE}) = 0.750$, $V(\widetilde{S}_{WAT} \geq \widetilde{S}_{WAS}) = 1.000$ $V(\widetilde{S}_{WAT} \geq \widetilde{S}_{MAT}) = 1.000$, $V(\widetilde{S}_{WAT} \geq \widetilde{S}_{GGE}) = 1.000$, $V(\widetilde{S}_{WAT} \geq \widetilde{S}_{REC}) = 1.000$, $V(\widetilde{S}_{WAT} \geq \widetilde{S}_{BIO}) = 1.000$.

$V(\widetilde{S}_{MAT} \geq \widetilde{S}_{ACC}) = 0.595$, $V(\widetilde{S}_{MAT} \geq \widetilde{S}_{ENE}) = 0.750$, $V(\widetilde{S}_{MAT} \geq \widetilde{S}_{WAS}) = 1.000$ $V(\widetilde{S}_{MAT} \geq \widetilde{S}_{WAT}) = 1.000$, $V(\widetilde{S}_{MAT} \geq \widetilde{S}_{GGE}) = 1.000$, $V(\widetilde{S}_{MAT} \geq \widetilde{S}_{REC}) = 1.000$, $V(\widetilde{S}_{MAT} \geq \widetilde{S}_{BIO}) = 1.000$.

$V(\widetilde{S}_{GGE} \geq \widetilde{S}_{ACC}) = 0.177$, $V(\widetilde{S}_{GGE} \geq \widetilde{S}_{ENE}) = 0.330$, $V(\widetilde{S}_{GGE} \geq \widetilde{S}_{WAS}) = 0.520$ $V(\widetilde{S}_{GGE} \geq \widetilde{S}_{WAT}) = 0.520$, $V(\widetilde{S}_{GGE} \geq \widetilde{S}_{MAT}) = 0.520$, $V(\widetilde{S}_{GGE} \geq \widetilde{S}_{REC}) = 1.000$, $V(\widetilde{S}_{GGE} \geq \widetilde{S}_{BIO}) = 1.000$.

$V(\widetilde{S}_{REC} \geq \widetilde{S}_{ACC}) = 0.177$, $V(\widetilde{S}_{REC} \geq \widetilde{S}_{ENE}) = 0.330$, $V(\widetilde{S}_{REC} \geq \widetilde{S}_{WAS}) = 0.520$ $V(\widetilde{S}_{REC} \geq \widetilde{S}_{WAT}) = 0.520$, $V(\widetilde{S}_{REC} \geq \widetilde{S}_{MAT}) = 0.520$, $V(\widetilde{S}_{REC} \geq \widetilde{S}_{GGE}) = 1.000$, $V(\widetilde{S}_{REC} \geq \widetilde{S}_{BIO}) = 1.000$.

$V(\widetilde{S}_{BIO} \geq \widetilde{S}_{ACC}) = 0.177$, $V(\widetilde{S}_{BIO} \geq \widetilde{S}_{ENE}) = 0.330$, $V(\widetilde{S}_{BIO} \geq \widetilde{S}_{WAS}) = 0.520$ $V(\widetilde{S}_{BIO} \geq \widetilde{S}_{WAT}) = 0.520$, $V(\widetilde{S}_{BIO} \geq \widetilde{S}_{MAT}) = 0.520$, $V(\widetilde{S}_{BIO} \geq \widetilde{S}_{GGE}) = 1.000$, $V(\widetilde{S}_{BIO} \geq \widetilde{S}_{REC}) = 1.000$.

It is necessary to calculate the minimum degree of possibility of $V(\widetilde{S}_j \geq \widetilde{S}_i)$ for i, j =1, 2,…, k as shown in Equation (12) [55].

$$V(\widetilde{S} \geq \widetilde{S}_1, \widetilde{S}_2, \widetilde{S}_3, \ldots, \widetilde{S}_k) = V\left[(\widetilde{S} \geq \widetilde{S}_1) \text{ and } (\widetilde{S} \geq \widetilde{S}_2) \text{ and} \ldots (\widetilde{S} \geq \widetilde{S}_k)\right] = \min V(\widetilde{S} \geq \widetilde{S}_i) \quad \text{for } i = 1,2,3,\ldots,k \quad (12)$$

Therefore, the minimum degrees of possibility of the model are:

$\min V(\widetilde{S}_{ACC} \geq \widetilde{S}_i) = 1.000$, $\min V(\widetilde{S}_{ENE} \geq \widetilde{S}_i) = 0.853$, $\min V(\widetilde{S}_{WAS} \geq \widetilde{S}_i) = 0.595$,

$\min V(\widetilde{S}_{WAT} \geq \widetilde{S}_i) = 0.595$, $\min V(\widetilde{S}_{MAT} \geq \widetilde{S}_i) = 0.595$, $\min V(\widetilde{S}_{GGE} \geq \widetilde{S}_i) = 0.177$, $\min V(\widetilde{S}_{REC} \geq \widetilde{S}_i) = 0.177$, $\min V(\widetilde{S}_{BIO} \geq \widetilde{S}_i) = 0.177$.

A weight vector W' is defined by Equation (13).

$$W' = (\min V(\widetilde{S} \geq \widetilde{S}_1), \min V(\widetilde{S} \geq \widetilde{S}_2), \ldots, \min V(\widetilde{S} \geq \widetilde{S}_k))^T \tag{13}$$

This vector should be normalized, giving the non-fuzzy weight vector *W*.

This research gives $W' = (1.000,\ 0.853,\ 0.595,\ 0.595,\ 0.595,\ 0.177,\ 0.177,\ 0.177)^T$ and normalizing $W = (0.240, 0.205, 0.143, 0.143, 0.143, 0.042, 0.042, 0.042)$.

Finally, it is necessary to assess the consistency of the judgements given by the decision maker, to ensure maximum randomness. The Consistency Index (*CI*) is calculated from Equation (14) to evaluate deviations from consistency in the judgements [56].

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{14}$$

The consistency ratio (*CR*) is calculated from Equation (15), in which the random consistency index (*RCI*) is generated by a random matrix of similar dimension to that evaluated and computed by Saaty [56].

$$CR = \frac{CI}{RCI} \tag{15}$$

If *CR* is less than 0.05 for a 3 × 3 matrix, 0.08 for a 4 × 4 matrix and 0.1 for matrices of higher order, then the judgement matrix is consistent [57].

The *CR* obtained is zero in the pairwise comparison matrix of the criteria.

A similar calculation process is followed with the subcriteria of waste and efficiency power criteria. In these cases, the *CR* obtained is zero and 0.069 in the pairwise comparison matrix of the subcriteria with respect to energy efficiency and waste respectively, and so the judgements made are consistent.

Adjusted AHP has been applied between the scale levels of criteria accident and biodiversity.

3. Results

The first health care organization (HCO1) analysed is a general hospital serving 300,000 inhabitants. There are some 400 beds of which 40% are surgical, 13 operating theatres, surgeries, and a staff of 1600 workers. There are 45 clinical services, and annual care activity is some 22,000 inpatients, and 180,000 outpatients.

The second health care organization (HCO2) analysed is a walk-in centre and so it only treats outpatients. It has a staff of around 25. There are 13 clinical services and 65,000 treatments annually.

In 2009 both HCOs were awarded the standard ISO 14001.

The assessment, from the model described, of HCO1 and HCO2 in 2010, 2011, 2012 and 2013 provide the results shown in Figure 3.

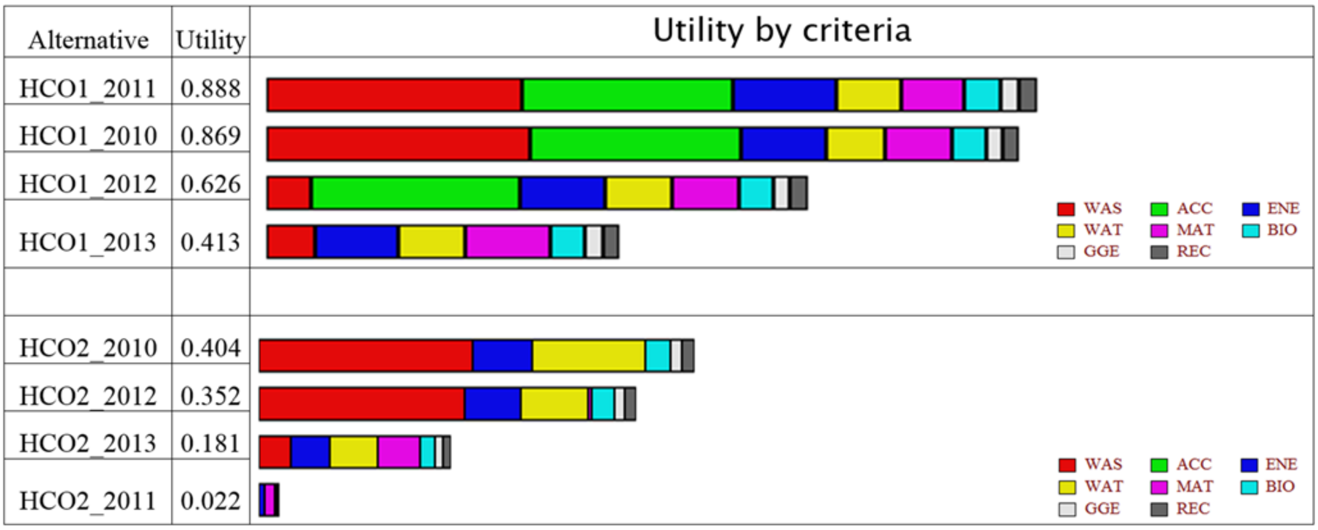

Figure 3. Assessment of health care organizations.

This assessment model imposes the need for continuous annual improvements, and also that these improvements should be made under the different criteria used. Therefore, the objectives of both organizations assessed which are considered positive show a negative annual trend in the criteria related to consumption, while the final objective sought is to have a percentage change per annual number of care services of −100% in the criteria related to consumption of materials, water and energy. For the criteria, recycling or renewable energy consumption the objective is set at +100%.

In the case of HCO1 it can be seen that there is very substantial improvement in 2011 because of the large drop of −16.16% in energy consumption per treatment with respect to 2010. This reduction stems from the performance of a series of actions for improving energy efficiency, with special focus on lighting. Firstly, they introduced a controller for electricity consumption which allows energy consumption to be determined by sectors; lamps were replaced by others with LED technology, which are more efficient and produce less light pollution; electromagnetic ballasts were replaced with electronic ones, movement detectors were installed and other systems for manual control of lighting. Also, the system for switching off the car park lights at night was automated, and informative panels were set up to increase awareness of the responsible use of energy [58].

Again, there was a significant increase in the consumption of renewable energy in 2011, of 17.08% per treatment with respect to 2010; this is because HCO1 has 440 solar panels giving one 1 MWh, which provide the annual consumption of approximately five operating theatres. This is part of the initiative of HCO1 to become involved in the European project RES hospitals, with the aim of achieving 20% of consumption through renewable energy by 2015. HCO1 also has a system of energy production by cogeneration, and 65% of the energy demand of the hospital comes from efficient systems.

HCO1 is a pioneer in Spain in the application of standard ISO 14064 for evaluation of greenhouse gas emissions. To this end, the sources of emission were identified, classified and quantified; anaesthetic gas was found to constitute 10% of total emissions and its emission had not been identified until that moment [59]. In 2011, emission of greenhouse gases was reduced by 15.58%.

There was also a very significant reduction (−15.51%) in 2011 in water consumption with respect to 2010. Actions such as the installation of water flow-reducing devices, separating the network of fire hydrants from the network of drinking water, and reducing the pressure of the water, have led to these improvements.

In addition, HCO1 has introduced criteria for administrative tendering which consider environmental factors when assessing offers. There has also been a great effort centring on the reduction in consumption of materials with environmental impact, such as plastic containers (a reduction of 12,000 containers per year), plastic bags (a reduction of 32,000 units per year), and in envelopes (10%). More efficient washing machines and dryers were purchased, as well as hybrid or electric vehicles and the detergents used are better for the environment [60]. However, in 2011 there was a considerable increase in dangerous waste (group III) due to the elimination of anatomical remains preserved in formaldehyde.

In 2012, there were increases in the consumption of resources such as water (1.42%), and energy (2.58%) per treatment with respect to 2011, which causes a drop in utility.

In 2013, there was a further increase in water consumption (0.99%), in group II waste (0.30%) and especially in group III (48.65%). This increase was mainly due to changes in the standards for segregating medicines to be discarded, since they are held to be dangerous waste, and so their containers also belong to this category. This has influenced the negative value of the change in recycling rate with respect to 2012. Furthermore, there has been an increase in the number of places for patients receiving cytostatic medicines, which has led to more waste of this type. Also, the sample storerooms have been cleaned, which contained anatomical remains in formaldehyde, and obsolete electrical equipment was disposed of. In 2013, there was an environmental accident involving a leak in diesel tank. All of this caused a significant decrease in the utility with respect to 2012.

HCO2 does not have renewable energy sources and so the assessment of this criterion does not contribute positively to the utility. HCO2 had its worst results in 2011. Although there is a decrease in energy consumption of 16.12% per treatment with respect to 2010, there are significant increases in water consumption (8.62%), group I waste (163.53%), group II (822.34%) and group III (346.98%). These increases in waste are due to the cleaning of x-ray waste, medicines disposed of, chemical residues and the replacement of toner in the printers. Nevertheless, the consumption of materials reduced by −55.74% per treatment with respect to 2010, and greenhouse gases reduced by −7.67%.

In 2011, an environmental training plan was started, with the aim of training the whole staff by 2013. This plan is based on providing knowledge about the types of waste generated, the bins to use and the internal circuit the waste must follow [61], with very positive results.

HCO2 improved its utility in 2012 with respect to 2011 because of a significant reduction in group I (−8.73%), group II (−84.78%) and group III (−93.56%) waste. However, there was an increase in consumption of resources such as energy (2.71%) (due to the poor weather and a greater need for heating) and materials (146.67%).

It should be borne in mind that remodelling or updating certain facilities or medical services led in many cases to the disposal of accumulated waste, with the consequent negative influence on the results given by the model. A similar effect is noted for the opening of new services or facilities.

In 2013, different criteria for HCO2 gave significant values. For example, energy consumption increased by 6.38% with respect to the previous year. Consumption of materials increased by 2.41% as test results began to be handed out on CD and the batteries of the medical equipment were replaced. There was also a considerable increase (414.24%) in group III waste, due to the replacement of toner. All this meant that HCO2 only had a utility of 0.181.

4. Conclusions

HCOs still can and should work on a variety of environmental questions, such as green purchasing. This concept is understood not only as a reduction in consumption of resources (paper and energy) when ordering from suppliers, but also the acquisition of materials and medical equipment with the least environment cost. For example: replacing mercury thermometers with infrared digital thermometers; creating protocols for buying purchasing and services which include environmental criteria for assessing offers; giving suppliers instructions for a suitable management of the environmental effects of their activity; requiring of suppliers the accreditation which guarantees the ability to carry out environmental control of their activity (segregation, withdrawal, transportation and subsequent valuation or disposal by authorized agents of the waste produced). When the service is completed suitable control of the environmental aspects should be established. External or internal noise is an important source of pollution, which is considered for example in the model in [17], however, it is not recognised by most health care organizations, although it would be very important to make a noise map of the organization to guarantee that it is within the legally established limits. The model described in this study does not analyse this criterion, although it should probably be addressed in an updated study. The transport of goods and services entering and leaving the hospital, and of staff and patients and their families who come to the hospital, is an important source of energy consumption (and of external noise).

Protection of biodiversity is a factor that is not generally considered in the environmental declarations analysed, as most HCOs are on urban land and so the implications for the protection of animal and vegetable species are considered to be minimal. Nonetheless, it should not be ignored because, though they may be on urban land, such organizations can have areas of trees within their grounds which should be protected. Specifically, a catalogue of trees could be drawn up, with an inventory of species present in the hospital grounds and surroundings. Rebuilding and development work in hospitals should take care to preserve all the trees and green areas which might be affected (including the animal species that might depend on them) and which have ecological or ornamental value. Similarly, treated waste water could be reused on the grounds.

The cost of fines and non-pecuniary sanctions resulting from not obeying environmental law could also be assessed. This is something that has not happened in the organizations studied or in other HCOs consulted, and so it has not been considered a criterion to be evaluated by the model. However, it could be a decisive factor in those countries or regions with lower environmental awareness.

Undoubtedly, environmental training is a key aspect in the reduction of environmental impact. However, it should not only involve clinical staff but should be broadened to include other workers in HCOs; in particular, the maintenance department is a key area in minimizing consumption of energy and material resources. Training should also be extended to patients, visitors, suppliers, subcontracted parties and other relevant groups. HCOs are mostly aware of the need to share knowledge about environmental protection, by organizing conferences and course, celebrating World Environment Day, no car days, meetings, surveys, notices, *etc.*

Environmental investment is valued and assessed by most HCOs, although it is not included in the model because it could introduce redundancy into the criteria, by evaluating both the investment and the consequences of this investment, such as reduction in consumption of water, energy, *etc.*

The use of renewable energies should be encouraged in HCOs. It is worth noting the RES-HOSPITALS Project, which has the aim of encouraging better strategy and sustainability with respect to reduction and production of energy, including a more efficient use of the opportunities offered by renewable energy in European HCOs. The challenge of this pilot project is to achieve a zero carbon hospital in the longer term and develop an investment plan for 50% of energy consumption from renewable sources by 2020. Fifteen hospitals participated in the project including five from Spain, four from Italy, three from the Netherlands and three from Poland. In addition, three HCOs from France, Hungary and the UK participated through a voluntary involvement in the consortium using their own resources [62]. This project has achieved significant savings in energy and reduction in CO_2 emissions, between 25% and 50%, by applying a number of novel ideas. In Spain, two hospitals included in the project have solar thermal systems. Although the main aim of the Spanish hospitals in the project is to focus on biomass to achieve a high percentage of renewable energy, they are also planning to invest in a solar PV facility on car park canopies and small scale wind turbines, biomass fired co-generation systems and roof-mounted solar PV panels [62]. However, changes in Spanish law have significantly reduced the incentives for renewable energy production and could delay or even cause cancellation of the introduction of these new technologies.

The 15,000 European hospitals produce around 5% of the CO_2 of the European Union. Furthermore, most of these face serious budget restrictions together with an increase in demand for care services. Many organizations need to replace outdated energy infrastructure with more efficient and flexible systems. This could lead to a reduction in the carbon footprint and the energy costs of hospitals but always with the aim of guaranteeing the energy supply, which is vital to preserving continuity of service in HCOs.

Without doubt, measures such as combining heat and energy to produce hot water for clinical use, adopting systems of natural ventilation, optimizing conditions of natural light in treatment rooms and offices, double facades, solar walls with transparent insulation, low energy double glazing, silencers in the exit pipes of the air conditioning units, new radiators and thermostats, floors and areas with similar periods of use, installation of manual control systems for lighting and movement detectors, purchase of electric vehicles, *etc.*, may contribute to guaranteeing environmental sustainability as well as the economic sustainability of the organization itself, becoming a standard in corporate social responsibility.

The model described in this paper is another approach which can contribute to improvement in environmental sustainability of HCOs. Unlike in a traditional audit, the model takes advantage of the use of Multi-Criteria Decision Analysis techniques; these allow objective modelling of the decision problem since one or more decision makers give judgements, which provide a value for the importance of each environmental question to the organization. It also has the capacity to analyse both quantitative and qualitative criteria simultaneously, and guarantees no redundancy in the assessment of items. Additionally, the fuzzy approach takes account of the uncertainty, vagueness or ambiguity of the judgements given by the decision makers.

This assessment model makes it obligatory to carry out continuous improvements and ensures that this is done with the various criteria used. The model uses criteria assessed per number of treatment services provided annually; in this way, the results can be compared over time within an organization and between different organizations, providing a tool for comparison or benchmarking between HCOs.

Future lines of work hope to apply the model to different healthcare organizations so as to compare the results according to such factors as the number of beds or of employees. The intention is to identify whether these or other factors influence the environmental utility of a healthcare organization.

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Conflicts of Interest

The author declares no conflict of interest.

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