Green Energy and Technology

Stefano Capolongo
Marta Carla Bottero
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Emanuele Lettieri *Editors*

Improving Sustainability During Hospital Design and Operation

A Multidisciplinary Evaluation Tool

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Foreword

Healthcare facilities, operating with an explicit mission of healing and stewardship, are uniquely positioned to both define and demonstrate the integration of health and sustainability into the promise of the twenty-first century's built environment. We know from the astonishing success of the green building movement that buildings can be among the most powerful drivers of positive human health, environmental, social, and economic outcomes. Reflecting this shift, aspirations regarding building performance are higher and more complex and challenge us to imagine what is possible: buildings as producers of energy, light, water, and food rather than consumers; buildings connecting people to nature rather than distancing them; buildings constructed of and maintained with healthy materials rather than manufactured with chemicals of concern; and, buildings that are beautiful and create conditions conducive to health. In short, buildings are viewed as intrinsic to the healthy and positive metabolism of the ecosystems that sustain life.

Ironically, however, while healthcare structures are the places where people experience the most intimate moments of their lives, all too often, impersonal technologies and unhealthful indoor environments dehumanize what should be the most humanistic of building typologies. Their prodigious use of energy, water, goods, and services coupled with enormous solid waste and wastewater outputs and transportation dependencies creates environmental stressors that compromise the public health. Their challenging work environments lead to high levels of stress, chronic illness, and workplace injuries that can undermine the delivery of care. Further, patients' exposure to unhealthful indoor environmental conditions can result in prolonged length of stay, increased medication, and hospital-acquired infections.

The notion that buildings can be a force for healing has a heralded legacy. This is particularly so for healthcare design. Florence Nightingale's prescient 'environmental theory' acknowledged the significance of fresh air, clean water, and sunlight as essential to restore patient health (Nightingale 1860); Alvar Aalto's Paimio Sanatorium in Finland is described as a "cathedral for health and an instrument of healing" (Mindel 2013); more recently, MASS Design Group's Butaro Hospital in Burera District, Rwanda resurrected the thematic underpinnings of Nightingale's environmental theory by relying on natural ventilation, sunlight, and connection to outdoors as fundamental design imperatives, and revived the traditional use of local materials as the project's primary building materials, employing more than 3,500 local people.

These structures and others like them, inspired by big ideas that come to life in tangible form through these architectural icons, garner widespread attention and stimulate important dialogue about the transformative potential of design. To what end? Often, operational quantitative and qualitative performance data are missing from the story. Feedback loops that correlate design decisions with operational outcomes are left incomplete. This absence of data restrains the ability to create a robust library of evidence-based design strategies of what works, and limits the ability to constructively and critically assess and evolve the places explicitly designed for healing so that they do, indeed, fulfill their mission of healing and stewardship. Such a 'learning community' of shared information would be a tremendous asset in establishing meaningful baselines and benchmarks.

While healthcare's mission aligns well with green building principles, customized tools and resources to integrate sustainability practices into the healthcare sector were slow to come, released years after commercial and residential building rating systems were well established in the marketplace. Efforts including the pioneering Green Guide for Health Care, followed by LEED for Healthcare, BREEAM for Health, and Green Star-Healthcare, represent the first generation of rating systems that align healthcare design practice around an explicit recognition of healthcare facilities' unique operational realities including 24-7 operations, caring for vulnerable patients, infection control, and unique regulatory requirements. The promise put forward with these early efforts is to position the facility as part of the healing continuum, indeed, a force for healing, and to recognize its significance at three scales: protecting the immediate health of building occupants; protecting the health of the surrounding community; and protecting the health of the global community and natural resources (GGHC 2005).

The Sustainable Healthcare Project's groundbreaking multidisciplinary tool represents a next generation effort that builds on these precedents. Its rigorous and pragmatic development process reflects three important and interrelated considerations. First, the tool is designed to be easy-to-use. Its focus on a user-centered approach informed by stakeholder feedback has the potential for widespread use and, therefore, broadly realized benefits. Many tools face the challenge of a robust development process but, in practice, are not widely used as they require too much time and effort. This is especially relevant in healthcare settings where time availability is at a premium.

Second, the tool is flexible enabling it to be customized to unique conditions and contexts of both operating and new facilities. The diversity of healthcare facility type as determined by specialization, size, location, and age requires a common framework with the opportunity for customization. Again, this should encourage the user to view the tool as relevant and yielding positive value: a motivator to use it.

Third, the tool is informed by the broadest definitions of health, *a state of complete physical, mental and social well-being and not merely the absence of* *disease or infirmity* (World Health Organization 1946) as defined by the World Health Organization, and of sustainability, embracing environmental, social, and economic considerations as defined by the 1987 Brundtland Report Our Common Future (World Commission on Environment and Development 1987). This breadth of scope is ambitious; it is also necessary.

Healthcare is one of the largest economic sectors in the global economy. Around the world, it touches millions of lives every day, whether as patients, staff, or visitors. In many towns and cities, it is the largest employer and measures among the largest 'footprints' of energy, water, waste, transportation, goods, and services. With such substantial influence, coupled with its formidable civic stature, the healthcare sector can leverage positive environmental, social, and economic transformation and promote physical, mental, and social well-being at the local, regional, and national scales. The Sustainable Healthcare Project's innovative tool is a welcome resource that can guide healthcare structures to realize their unique potential as a substantive force for health and sustainability.

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We would like to heartily thank Gail Vittori for the foreword and the staff of the hospitals where we applied our evaluation system, who have been happy to share their deep technical knowledge, while fulfilling their daily tasks.

The Research Group

Andrea Bellagarda, is graduate in *Industrial Production and Technological Innovation Engineering* from Politecnico di Torino, worked on economic sustainability studies focusing on managerial solutions.

Matteo Birocchi, a graduate in *Building Engineering* from Politecnico di Milano, worked on the environmental side of the rating system and on the following evaluation, focusing especially on building engineering aspects related to envelope technologies and performances.

Marta Carla Bottero, Ph.D. in Geo-environmental engineering is assistant professor of Project Appraisal and Planning Evaluation at Politecnico di Torino. Her scientific interests are related to the sustainability assessment of urban and territorial transformations, with particular reference to multi criteria analysis.

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Stefano Capolongo, is associate professor at Politecnico di Milano and is also a teacher at the Post-graduate Schools of Hygiene and Preventive Medicine at the Universities of Parma and Milan. Scientific head for the Politecnico di Milano's Cluster on "Designing healthcare facilities" and Director of Master's program in "Scheduling, planning and designing public healthcare facilities". He is the principal academic tutor for the SustHealth research project.

Elisa Cavagliato, is a graduate in *Architecture* (*Construction*) from Politecnico di Torino, focusing her attention on architectural features that affect environmental sustainability and on interior elements which are involved in social sustainability.

Arlind Dervishaj, is a graduate in *Architecture* (*Construction*) from Politecnico di Torino, who participated in the project developing architectural strategies mainly concerning comfort issues.

Michela di Noia, a graduate in *Architecture* from Politecnico di Milano, developed and implemented solutions for humanization and social sustainability.

Giulia Gherardi, an engineer, graduate in *Management Economics and Industrial Engineering* from Politecnico di Milano, contributed to the evaluation system by creating and implementing the criteria that measure economic sustainability.

Marco Gola, an architect, graduate in *Architecture for Sustainability* from Politecnico di Torino, analyzed architectural and urban planning issues, linked both to social and environmental sustainability. He is a Ph.D. candidate in Politecnico di Milano at the ABC Department.

Emanuele Lettieri, is assistant professor at the Politecnico di Milano. His research interests deal with the assessment of technological and organizational innovation in healthcare. He is lecturer of Business Economics and Organization at Politecnico, where he is also lecturer of Health Technology Assessment and Management Accounting for postgraduate courses, and Director of the Part-Time International MBA program.

Francesco Mantua, is a graduate in *Energy and Nuclear Engineering* from Politecnico di Torino explored and applied the energy components which are related to the environmental impact of a newly designed healthcare facility.

Slobodan Miljatovic, is a graduate in *Environmental and Land Planning Engineering* from Politecnico di Milano, examined factors and solutions that involve water and waste management influencing the ecological footprint of a hospital.

Maria Nickolova, a graduate in *Architecture* from Politecnico di Milano, was responsible for the development and implementation of the social sustainability criteria that assess the humanization of a future healthcare structure.

Marco Rostagno, an engineer, graduate in *Architecture for Sustainability* from Politecnico di Torino, studied the urban design and use of specific materials that have an effect on the environmental performance of a new hospital.

Salvatore Speranza, a graduate in *Energy Engineering* from Politecnico di Milano, focused on environmental sustainability studying resource consumption and energy production.

Lia Volpatti, a graduate in *Biomedical Engineering* from Politecnico di Milano, handled biomedical and clinical issues related to the project.

Contents

Acronyms

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BREEAM	Building Research Establishment's Environmental Assessment Method
C&I	Criteria and Indicators
CEO	Chief Executive Officer
CHP	Combined Heat and Power
EHCI	European Health Consumer Index
EPP	Environmentally Preferable Purchasing
GDP	Gross Domestic Product
GGHC	Green Guide for Health Care
HCWH	HealthCare Without Harm
HVAC	Heating Ventilation and Air Conditioning
ICH	Humanitas Research Hospital
ICU	Intensive Care Unit
ISQua	International Society for Quality
ITACA	Istituto per l'Innovazione e la Trasparenza degli Appalti e la Compatibilità Ambientale
JCI	Joint Commission International
LEED	Leadership in Energy and Environmental Design
NGO	Non-Governmental Organization
NHS	National Health Service
OECD	Organization for Economic Co-operation and Development
UNI	Ente Nazionale Italiano di Unificazione
USGBC	United States Green Building Council
WACOSS	Western Australian Council of Social Service
WHO	World Health Organization
WMP	Waste Management Plan

Chapter 1
Healthcare Sustainability Challenge

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Abstract Healthcare structures are supposed to protect and improve Public Health, but in the meanwhile they are highly energy-demanding and socially impactful structures, which cause negative side effects on the people's health and on the environment. Building hospitals able to cope with the definition of Health as complete well-being and which can fit to the future means therefore constructing sustainable structures. Such complex realities work as a whole, single organism, that can be robust and productive only if every single part is healthy. So when it comes to healthcare facilities, sustainability has to be taken into account as both a main requirement and a quality issue, since they must be capable to deliver high standards also in changing circumstances. Starting from these assumptions the Sustainable High Quality Healthcare project is born with the aim of providing a new original insight into such a complex subject. Its goal is to define, through the construction of an innovative assessment system, solutions and strategies towards the realization of sustainable existing operative or in-design hospitals, where sustainability applies to the main macro-areas.

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Keywords Healthcare · Sustainability · Obsolescence · Existing hospitals · In-design hospitals · National health service · SustHealth

Being Sustainable in Healthcare

According to the World Health Organization (WHO), *Health* can be described as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization 2012). Although this definition has been subject to controversy, in particular as lacking operational value and because of the problem created by use of the word 'complete', it remains the most enduring one (Callahan 1973). Within this context, healthcare providers carry out those crucially important activities aiming to promoting good health in humans by systematically preventing or curing health problems. Healthcare can thus be described as "the prevention, treatment and management of illness and the preservation of mental and physical well-being through the services offered by the medical and allied health professions" (Medical Dictionary 2012).

Access to healthcare is deeply influenced by a variety of social factors such as economic conditions or existing national health policies, thus greatly varying across countries, populations and individuals (Capasso et al. 2014). Undoubtedly though, regardless the system that is taken into consideration, there is one symbol that is universally recognized as representing the healthcare system being in its most complex, and diverse structure: the hospital. A hospital is a healthcare institution where patients are systematically treated by specialized staff and equipment or, more generally, an institution providing medical and surgical treatment and nursing care for sick or injured people (Oxford Dictionaries 2012).

Public health is recognized as a resource that must be preserved and improved. Within this context, hospitals are the healthcare system's most recognized structures pursuing this goal: one would therefore, naturally, believe such structures to be designed to protect public health. Continuous studies though have unveiled how traditional hospital structures, theoretically built to preserve public health, actually

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have an indirect negative effect on public health and, on a wider level, on the community and environment they are set in.

The Italian hospital network, with its 1,170 hospital structures spread across the country, is not only extremely complex but also considerably old. Italian hospital structures are, on average, outdated both in their infrastructures and, especially, in the way they have been designed. Today, fewer than 50 % of these structures have been opened, less than 20 years ago, with 5 exceptional hospitals having been functioning in the same facilities since before the 1900 (Nuovo Sistema Informativo Sanitario 2006). Most importantly though, if one considers the average time which passes between when a hospital is designed and when it is finally opened almost 80 % of the operating structures in Italy have been conceived over 20 years ago (e.g. the Humanitas Research Hospital in Rozzano, Milan, which is a best-in-class example within the Italian reality, took 10 years to be completed (Colombo 2012). Only in the region of Lombardy, for example, which has often been cited because of its concentration of well-managed and well-operating structures, 45 % of the hospitals are now well over 65 years old (Capolongo 2006).

If one therefore considers the traditional problems that affect the National Health Service (NHS) and its hospital network, the Italian hospital reality is brought to face an even more difficult scenario because of the age of its healthcare infrastructure.

The recent increase in public conscience towards environmental issues has brought an immediate focus on the importance of environmental sustainability: whereas hospital facilities are the symbol of a system supposed to defend people's health, their outdatedness actually brings them to be part of those structures which pose the greatest threat to us if put into the environmental perspective. There are therefore increasingly more issues facing hospitals on the environmental front, with regulators and communities now clearly changing their expectations of healthcare facilities for energy reduction and environmental improvements (Cantlupe 2010).

The involuntary negative impacts that hospital structures may have on their communities and on the environment affect a variety of fields, with this being even more true for outdated facilities. From the environmental point of view, for example, the existing hospitals are extremely complex buildings that have more or less three times the energetic consumptions of a residential building with the same size, not to mention their water consumption. Furthermore, these often obsolete structures continuously produce high amounts of air emissions (in the United States, the Department of Energy states the nation's hospitals contribute 2.5 times the carbon dioxide emissions of commercial buildings), together with solid and liquid wastes which also can be dangerous or toxic. Hospitals generate an excess of 2 million tons of general waste each year: according to a Johns Hopkins University study, they are the second largest waste producers after the food industry (Cantlupe 2010). Hospital structures also have a noteworthy social impact: their establishment within an urban or suburban center significantly alters the location's equilibrium, for example through the naturally consequent increase in traffic, noise and surrounding means of transportation. Furthermore, their spaces host a variety of different individuals, cultures, stories and professional backgrounds, all framed within an extremely delicate environment where joy and pain are intrinsically intertwined. Once again, the inconveniences in such spheres are particularly emphasized as the hospital's age increases, both because of the obsolescence of the project and of course, because of the unavoidable transformations that both the hospital's facilities and its urban setting face over time.

Parallel to this, healthcare forms a significant part of a country's economy but according to the WHO, a well-functioning healthcare system requires a robust financing mechanism; a well-trained and adequately-paid workforce; reliable information on which to base decisions and policies; well maintained facilities and logistics to deliver quality services (World Health Organization 2012). This, of course, requires healthcare sustainability to be increasingly considered from an economic point of view, especially in countries such as Italy that traditionally have reached almost uncontrolled healthcare spending levels while functioning in outdated designed facilities, both from the architectural and operational point of view. In fact, hospitals drain a substantial amount of financial resources from either their community or their users: only for energy costs, hospital structures in the United States, for example, spend more than $5 billion annually (Index Mundi 2012). In 2010, the healthcare industry consumed an average of 9.5 % of the Gross Domestic Product (GDP) across the most developed Organization for Economic Co-operation and Development (OECD) countries, with the United States (17.6 %), the Netherlands (12 %), France and Germany (11.6 %) being the top spenders.

Within this context, Italy placed itself slightly below OECD average with 9.3 % of GDP spent on healthcare activities in 2010 (Nuovo Sistema Informativo Sanitario 2006). A more in-depth analysis of the Italian healthcare system though reveals a worrying scenario: from 2005 on, the Italian's NHS expenditures have continuously increased, as clearly showed by Fig. 1.1. This has brought the average Health Service cost to almost €2,000 per capita, in a country where the average person's income did not exceed €29,900 (Index Mundi 2012).

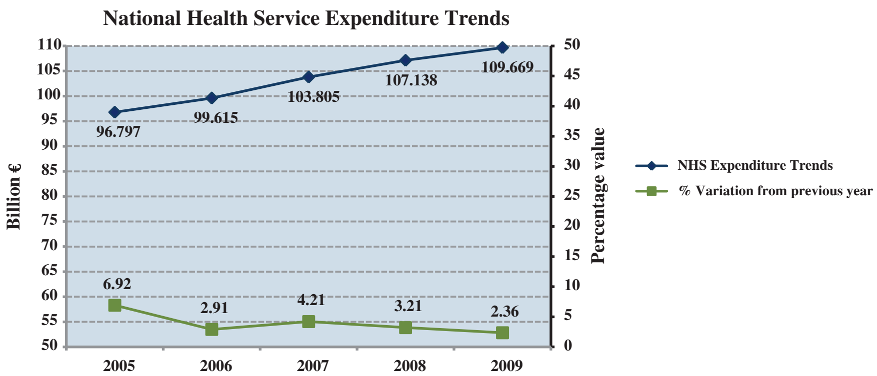

Fig. 1.1 Italian national health service (NHS) expenditure trends. The data of the graph are taken from Index Mundi

Furthermore, if the ratio between this NHS expenditure and the overall national GDP is taken into consideration, continuously increasing NHS costs combined with a currently unfavorable economic scenario result in a drastic increase of the overall NHS impact on the country's economic tissue, as the trends from Fig. 1.2 clearly show. Most importantly though, Fig. 1.3 historic data clearly shows how, parallel to this continuous increase in its expenditures, the Italian NHS system is also constantly struggling to cover its costs which regularly exceed those forecasted by the annual national budget, and for which only a certain amount of economic resources were preventively assigned.

The remaining costs, sum up to at least 3 % of the nation's GDP, must then be covered by redirecting resources that could, or should, otherwise be dedicated to different projects.

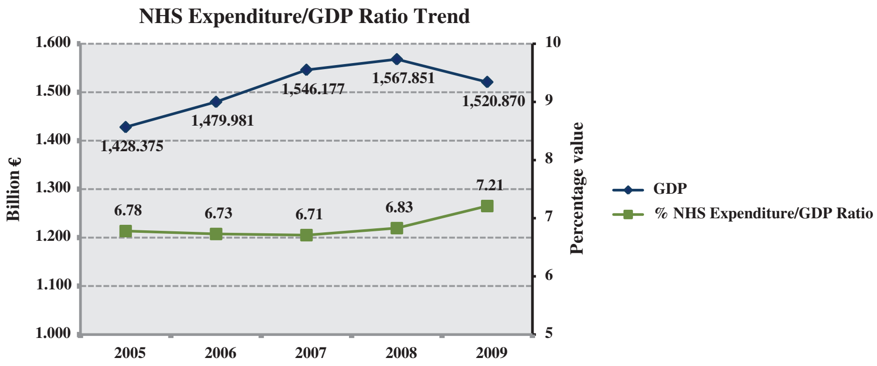

Fig. 1.2 Italian NHS expenditure and GDP trends. The data of the graph are taken from Index Mundi

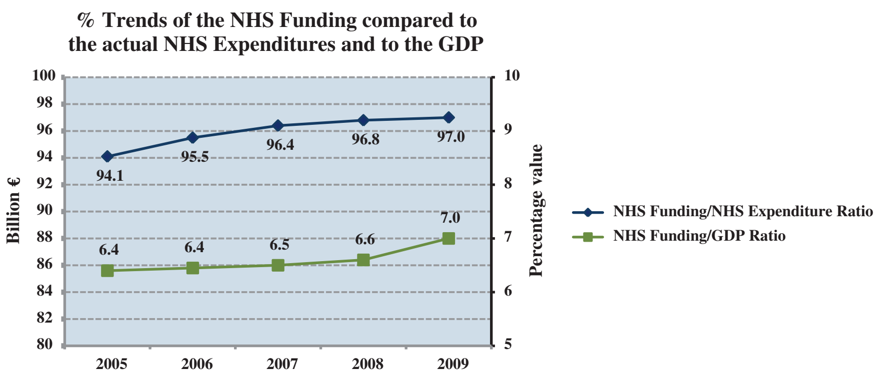

Fig. 1.3 Italian NHS expenditure and GDP trends. The data of the graph are taken from Index Mundi

A careful study of the Italian healthcare system and, especially of its outdated hospital network therefore clearly reveals how the country is currently incapable of facing the new challenges and needs from the healthcare field.

The most recent threads in sustainability have unveiled what can now be considered as the ultimate goal for sustainability itself: social sustainability, or the impact that the surrounding activities have on what concerns people. Within healthcare, in particular, understanding the human sphere is of fundamental importance: from the impact this can have from the clinical point of view, to the people who work in such a demanding environment; from the impression and support that hospital staff and environment can give to those who visit or live in this environment on a daily basis, to the most personal and emotional point of view. Structures conceived with architectural principles from 20, 30 or 40 years ago are today often not adequate to satisfy this sphere of concern, first of all because the care concept has changed from *disease cure* to *person care* (Spinelli et al. 1994). The attention dedicated to spaces, visiting or intimacy has drastically changed as the importance of these factors shifts towards the hospital's users.

As Dr. J. Koster, president and Chief Executive Officer (CEO) of Providence Health and Services, a WA-based company which runs 27 hospitals and employs about 49,000 people, once pointed out hospitals not only have a huge environmental footprint within the communities they serve, they often are also the community's largest employer and therefore have responsibilities which go beyond caring for patients: in fact, leading hospitals, that have been working for years to attain energy and environmental sustainability, have an organizational structure with designated sustainability officers and green teams with clear authority from CEO. This comes down to a 'triple bottom line', as Dr. R. Beam, system director of construction and sustainability in the office of supply chain management for Providence, pointed out: long-term sustainability for the planet and humanity can be achieved integrating performance of environmental practices, social and financial benefits (OECD 2012). One can therefore understand how healthcare infrastructures' out-datedness, even appearing as an insurmountable obstacle to hospitals sustainability at first glance, can still be overcome, as long as a deep change is performed. What the Italian healthcare system, in particular, and its hospitals truly require is therefore a committed, dedicated guidance towards sustainability, aiming to develop an environment where everyone collaborates to bring personal contribution towards the achievement of sustainability.

Sustainable Healthcare Project Objective

Public Health is universally recognized as a valuable resource that must be preserved and improved. Health's promotion needs a new system of healthcare buildings that can meet the current and future social demand, being, at the same time, environmentally and economically sustainable.

Fig. 1.4 SustHealth' logotype

Starting from these assumptions the **SustHealth** (Sustainable High Quality Healthcare) project (Fig. 1.4) was born with the aim of providing an original insight into such a complex subject. It has been developed as a multidisciplinary research project, carried out by a team of students, from the schools of Engineering and Architecture, academic tutors and sponsoring companies, with Alta Scuola Politecnica, the joint excellence program of Politecnico di Milano and Politecnico di Torino (Italy).

The goal of the Sustainable Healthcare project is that of developing new strategies that can make the hospitals more sustainable, while also elaborating new guidelines for the planning, management and design of such sustainable hospitals. This broad scope has been narrowed down to a more specific objective: that of conceiving a solution capable of supporting hospital structures in making decisions towards sustainability promotion and improvement.

The need for an assessment system to promote sustainability comes from considerations about the heavy impact that hospitals have on the social, environmental and economic spheres. Within this context, the Sustainable Healthcare project's objective has been that of designing a new tool capable of supporting hospital structures in understanding where they lack in the three sustainability areas and then to guide them in making decisions capable of promoting an environment where sustainability is both understood and continuously promoted and improved. More specifically, the study focused on satisfying a specific requirement: the need for an effective, reliable and especially replicable tool for the evaluation and measurement of the operating and designing hospitals' sustainability, which led the teams to develop an innovative evaluation system based on specific criteria.

As prof. F. Butera, an expert in sustainability matter, would say, it is necessary to operate within a new paradigm in which the choices are confined within a pentagon; at its vertices there are five keywords: *ethics, aesthetics, economy, ecology, energy* (Butera 2012).

This tool has been imagined as an evolution of all the available sustainability evaluation systems, which somehow lacked the wider prospective envisioned by the SustHealth project. Indeed, these evaluation systems prevalently focused on deeply assessing the environmental features that should be taken into account when designing a new building, without considering neither how the design phase, influence the economic and social aspects nor how the operative structure actually performs in any of these spheres.

Method of Work

The Sustainable Healthcare project developed a standard method of work that can be easily applied to the development of any project requiring the application of innovative solutions to an existing scenario:

- understanding the scenario, with particular focus on the different sustainability issues of healthcare structures, on the main stakeholders interested by such themes and on the relationship between such stakeholders and, especially, their needs;
- identification and study of the so-called 'state of the art' solutions, in this case represented by:
  - hospital structures which have been internationally recognized either for their excellence in one or more sustainable areas, or for any other practices which could directly or indirectly interest the Sustainable Healthcare project's activities;
  - hospital evaluation systems, with focus on their attention, or lack thereof, to healthcare sustainability;
- further study of the identified 'best-practices', represented by the healthcare structures and evaluation systems which were most relevant to the Sustainable Healthcare project, through:
  - interviews both to major experts in different technical and managerial fields and to experienced professionals from the healthcare system;
  - on-site visits to the identified best-in-class examples of European healthcare sustainability;
- data processing of the previous steps, highlighting positive and negative aspects of the different strategies of evaluation and legislative systems for the compliance of the strategies to the emerging needs;
- summarizing the acquired information into a comprehensive evaluation system, capable of assessing the three different sustainability areas, by: development of a set of straightforward criteria aiming to evaluate the hospital's performance in different areas, related to the three sustainability spheres; submission of the criteria, indicators and their specific evaluating questionnaires to an expressly created focus group, composed by the previously mentioned experts and professionals, in order to identify their relative weight according to their improvability in these structures; analysis of the obtained results with a specific software to define the relative weight of the different criteria and of the three sustainability areas within the hospital's global evaluation;

- testing and application of the developed tool on two partner healthcare structures, one operative and one in-design;
- development of a comprehensive sustainability evaluation of each analyzed structure, including guidelines toward sustainability improvement.

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Chapter 2
Current Scenario Analysis

Stefano Capolongo, Maddalena Buffoli, Michela di Noia, Marco Gola and Marco Rostagno

Abstract The analysis of a scenario as complex as a healthcare facility cannot be accomplished only through theoretical studies: researches have therefore been conducted by taking into account the mainly acknowledged theories and by directly experiencing the hospital reality with a user-centred perspective. The stakeholders' analysis highlighted how diverse are the groups of people which may have any interest in healthcare, ranging from Public Administration to employees and patients, to volunteers and local communities. However, their needs and the possibly arising controversies can be defined, taking into account overlapping and interrelationships, according to the three pillars of sustainability: the environmental, social and economic spheres. Through the analysis, by means of interviews and on-site visits, of different case-studies in Italy and sustainability best-practices around Europe were individuated the Niguarda Hospital, the Hospital del Mar, the Humanitas Research Hospital, the Meyer Hospital, the New Legnano's Hospital and the next New Karolinska Solna Hospital. It was then possible to identify more specific and concrete users' needs, to be translated into specifications for the newly developed tool. Every hospital represents a peculiar reality, dealing with many common concerns, but also with numerous issues tightly related to the local context.

Keywords Stakeholders · Niguarda Hospital · Hospital del Mar · Humanitas Research hospital · Meyer Hospital · New Legnano's hospital · New Karolinska Solna Hospital

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The scenario analysis necessary to the development of a user centered tool was carried out mainly through two different means.

On one hand, a focused literature analysis, aiming to better understand the issues related to operative hospitals and their design process and also to deepen the different facets of the sustainability concept.

On the other hand, on field studies, conducted by visiting some of the most innovative and modern hospitals in Italy and Europe and through comprehensive meetings with scholars and designers who already tackled the issue of sustainability in healthcare.

Stakeholders Analysis

Considering the extremely delicate role covered by the healthcare structures both within local communities and wider society in general, the number and variety of stakeholders who could claim an interest in the Sustainable Healthcare project is noteworthy. Such stakeholders range from interest groups who directly interact with hospitals on a daily basis, such as employees, patients, visitors, suppliers of goods and services, to those who find themselves to interact indirectly but continuously with hospitals, being located next to these structures, as the local communities. An important group of stakeholders is also represented by the local public and private institutions who affect or are affected by the hospital's activities, varying from the Non-Governmental Organizations (NGOs), involved in supporting the patients and their family members, to the local Public Administration, which approves the structure's budget on a yearly basis. In this scenario it is fundamental to have an innovative approach that takes stakeholders' opinions and needs into consideration, establishing cooperation between them and designers.

Considering the scope of the project, which focuses on improving the hospital's performance under three different sustainability profiles, the stakeholders were divided according to the sustainability area they belong to (Fig. 2.1). The relationships between them were studied together with the main controversies which had to be considered during the development of the identified evaluation tool. Controversies, quoting Prof. T. Venturini, "are the place where the most heterogeneous relationships are formed" (Venturini 2009). The understanding that, by definition, the requirements of different stakeholders are likely to be in conflict with one another and that the project would therefore have to define and justify a certain level of compromise was therefore, of course, a crucial step in the project's development.

The study of stakeholders and the analysis of relations among them have been used to define the path which led to the creation of the assessment system. This was done while keeping in mind the necessity to balance the different topics of sustainability and to satisfy all the different stakes present during the hospital design and operative phase.

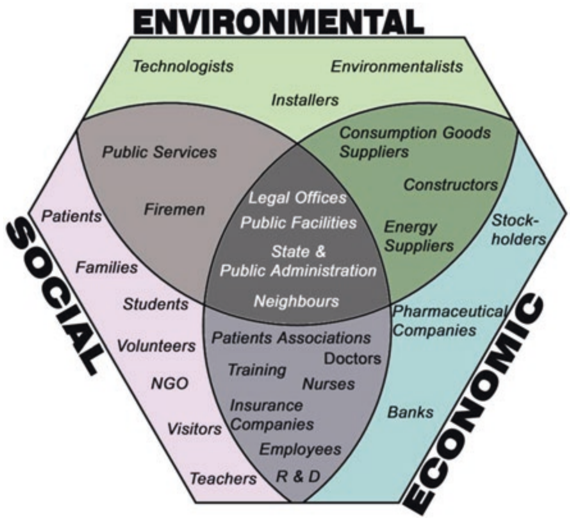

Fig. 2.1 The relationship between the sustainable healthcare project's stakeholders

Learning by Visiting

As the method of work clearly underlined, following the preliminary study of the 'state of the art' situation concerning existing healthcare sustainability evaluation systems, sustainability issues in operative and in-design hospitals and, especially, the different standpoints of scholars and professionals on the subject, the project proceeded with the identification of a list of 'best practices'. The project's activities therefore shifted from an initially theoretical approach, aiming to help the understanding of the context within which the healthcare structures are required to operate, to a more practical one, where the findings and impressions gathered during the academic phase were compared, developed and discussed directly with professionals, academics and hospital users, such as patients and visitors.

In order to better satisfy the need to observe and understand the operative hospitals' issues from a sustainability-focused point of view, the different stakeholders were contacted according to the sustainability sphere affected by their activities, rather than by their individual role. For example, hospital staff was interviewed on separate occasions, first for its role as stakeholder in hospital humanization (one of the founding pillars of social sustainability) and then as manager of the different wards (focusing on economic sustainability). These face-to-face interviews involved a variety of profiles: architects and engineers dealing with the hospital's preservation and continuous maintenance; administrative executives and doctors handling managerial issues; technicians and members of staff responsible for the operational maintenance of the structure and of its installations; doctors, nurses, patients and visitors experiencing the daily impact of the hospital's functioning;

local communities and public administrators involved in the effect that the hospitals' presence had on their neighborhoods.

Furthermore, interviews were included in wider on-site visits to various hospital structures, visits which allowed to understand and appreciate the complexity of these structures as a whole, going beyond the own area of specialization, and therefore to develop a true multidisciplinary point of view. During the scenario analysis some buildings were specifically used as case studies.

These structures, both Italian and foreign ones, vary from buildings built in recent decades to hospitals that have been converted over the course of their lifetime. The selected case studies, internationally identified as *best practices* as far as building sustainability issues are concerned, were analyzed and visited, gathering information for each building according to:

- economic sustainability;
- social sustainability;
- environmental sustainability.

Niguarda Hospital, Milan, Italy

The Niguarda Hospital (Fig. 2.2) is located in the northern area of Milan. The hospital was founded in the 30s. The complex, constituted by pavilions, has a monumental entrance and includes art elements, such as statues and decorations, which recall the ancient Lombardy hospitals (Crippa and Sironi 2009).

During the years the complex and its pavilions were subjected to several changes, additions, renovations and transformations, underlying the strong relationship and integration that the buildings have with their surroundings.

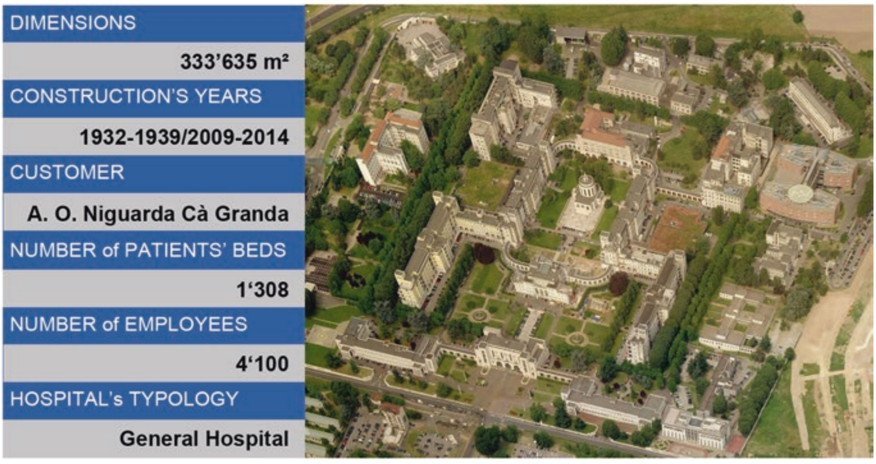

Fig. 2.2 Aerial photograph of the Niguarda Hospital

Following a list of the most noteworthy practices applied at Niguarda Hospital towards sustainability.

Economic sustainability:

- Realization of an annual *Sustainability Report,* analyzing the structure's budget and the social and environmental issues.
- Development of automated transports due to the concentration of healthcare activities in three different poles. The historic underground connections have a length of about 4,300 meters, that are viable by small vehicles, and they reach all the buildings.

Social sustainability:

- Clear signals in order to favor user's sense of direction. The pavilion's numbering is progressive with numbers increasing from left to right.
- Wide internal courtyard with the function of commercial space reception information and waiting area.

Environmental sustainability:

- Integration and interaction between the newly developed and the existing buildings through the reuse of the historical heritage.
- Strong focus on green areas, which are easily accessible by patients.

Hospital del Mar, Barcelona, Spain

Hospital del Mar is located in the area of Barceloneta (Fig. 2.3). Its story starts in the middle of the XX century, with the aim of transforming a degraded neighborhood into a new heart of the city. Today the hospital is undergoing a new transformation following the principle of the Phoenix, under the outstanding guide of Arch. A. De Pineda. Next to the hospital there is the new research center with a circular shape, accessible through a large entrance open to the public, which hosts several national and international innovative departments and laboratories (Capolongo 2006).

Following a list of the most relevant solutions applied at Hospital del Mar towards sustainability.

Social sustainability:

- Special attention to humanization and well-being through soft indoor colors and natural widespread light.
- Covered public square dedicated to meetings open to the public.
- Linear building with two floors topped by a projecting roof, overlooking the sea.
- Double corridor organization of offices and ambulatories in the first floor, which allows separation from staff and public ones.
- Separation, at small distance, of the hospital from the research center, to avoid intertwining with the flows related to on the medical wards' activities.

Fig. 2.3 Aerial photograph of the Hospital del Mar

Environmental sustainability:

- Accessibility with public transports.
- Good integration with the urban context.
- Use of passive building systems for the new biomedical research center, e.g. an external coating constituted by a double skin of wood and glass.

Humanitas Research Hospital, Rozzano, Italy

The Humanitas Research Hospital (ICH) is considered one of the most interesting hospitals in Italy as a concrete example of environmental, social and economic sustainability and of their holistic integration (Fig. 2.4).

As stated in a Harvard Business School study, the hospital has an innovative design in which the wards and the medical services blocks are separated.

ICH has been certified by the Joint Commission International in 2002, 2006, 2009 and 2012, demonstrating to be one of the Italian best examples in terms of healthcare sustainability. Following a list of the most noteworthy practices applied at Humanitas Research Hospital towards sustainability (Colombo 2012).

Economic sustainability:

- Lean Transformation which aims to create a culture of continuous improvement in the quality of care provided to patients by seeking to eliminate waste.
- Internal developing courses, which, according to the Staff Education and Qualification department, proved to be more effective and an important source for individuals to feel part of a community.

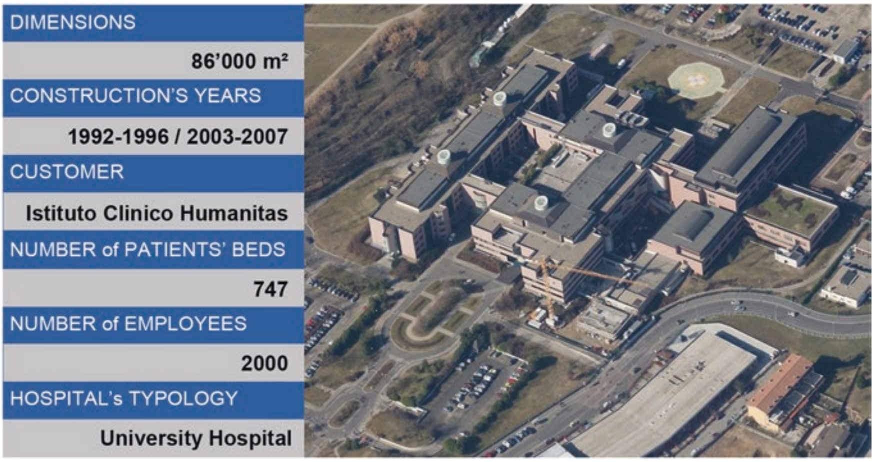

Fig. 2.4 Aerial photograph of the Humanitas Research Hospital

Social sustainability:

- Architectural design configured around four light wells arranged in a square; in the medical service block, imaging, nuclear medicine and other services are located on the ground level, outpatient clinics on the first floor, operating rooms and ICU department on the second floor.
- Recovery wards placed in different wings of the same building.
- The project aims to minimize the distances that patients needed to be moved and maximized natural sunlight to create a pleasant outcome.
- Minimization of the distances that patients need to cover.

Environmental sustainability:

- Maximization of natural sunlight to create a pleasant environment.
- Walls of the medical service area built with plasterboard that allows future changing in response to new technology or changes in the patient flow.

Meyer Hospital, Florence, Italy

The Meyer Children's Hospital (Fig. 2.5) is located in the area of Careggi, in Florence. The hospital was realized with the aim of giving new life to Villa Ognissanti, a milestone facility in the city's healthcare system dedicated to the cure of tuberculosis. Meyer's creative project was innovative from a variety of points of view: first of all it was fully designed for children, it was conceived to perfectly fit within the surrounding landscape and existing buildings and to be environmentally friendly (Del Nord 2006).

The project was demanding and challenging in its execution, but gave rise to a hospital capable of creating a wide system, involving its surroundings: other

Fig. 2.5 Aerial photograph of the Meyer Hospital

than including a mimetic operation, Meyer's design concept allowed to develop a hypogeal building in the existing Careggi hill. Following a list of the most relevant solutions applied at Meyer Children's Hospital towards sustainability.

Social sustainability:

- Centrality of the young patient in the design concept.
- Selection of special construction materials, including glasses, which allow to contain the noise on the façade of the building within 50 dB during daytime.
- Positive humanization effectively achieved through indoor comfort, green and play areas, interrelation between external and internal spaces, use of natural and recyclable materials, widespread quality, absence of indoor pollution.

Environmental sustainability:

- Energy-efficient technologies and photovoltaic panels located on windows.
- Appropriate bioclimatic conditions ensured through the high insulation provided by the roof garden that concurs to energy balance and climatic comfort.
- Natural ventilation used to maintain an optimal micro-climate and a direct relation between inside and outside, reducing the sense of isolation.

New Legnano's Hospital, Legnano, Italy

The new Legnano's Hospital is characterized by a modular structure that facilitates any future expansion (Colombo 2012). The structure is technologically advanced but at the same time user friendly. It consists of low-rise buildings, courtyards and

Fig. 2.6 Aerial photograph of the New Legnano's Hospital

squares and is divided into departments that ensure spatial contiguity between areas of greater interaction. The areas for hospitalization, diagnosis and treatment make up 50 % of the total area. The remaining 50 % is made up of areas that host services for the public, including shops (Fig. 2.6).

One of the biggest merits of this hospital is the new approach which was applied for its design and organization, including the following solutions, which are sustainability best-practices.

Social sustainability:

- Good flows project 80 % of the patients find their destination quickly on the first floor.
- Emergency department designed to have the shortest possible distance from every point of the structure; moreover external providers never get in contact with patients.
- Various campaigns to teach people about disease prevention and help them facilitating the process of interaction.
- Wards and operating rooms are planed according to the medical staff's needs and to a participatory policy.
- Flexibility of interior and technical spaces to face technology progress.
- Organizational solutions to provide maximum elasticity and autonomy to each part of the building. The innovative bidirectional structural system gives the possibility to use the spaces for almost all types of functions.

Environmental sustainability:

- The hospital is powered by a network of district heating and cogeneration.

New Karolinska Solna Hospital, Stockholm, Sweden

The New Karolinska Solna Hospital, designed by White-Tengbom architects, can be considered a good example of sustainable hospital for the future (Fig. 2.7).

The goal of the new university hospital, which will open its doors to the first patients at the end of 2016, is to provide highly specialized healthcare and conduct basic research, patient-focused clinical research and education. Greater collaboration between healthcare and research will contribute to faster research findings towards the development of new treatments and drugs (Capolongo 2013).

The aim of the project is to reach the Gold class in the LEED certification system, through many examples of best practices in different fields, as listed below.

Economic sustainability:

- Mutual support between hospital and University, within the management of the County Council.

Social sustainability

- Distinct focus on the patient: patient's safety integrity and comfort are at the center.
- Purpose-built environment that facilitates the healing process and stimulates patients and staff.
- Attention to Daylight: daylight factor is higher than 1.2.

Environmental sustainability:

- Xeriscaping landscape to minimize water use and waste.
- Energy supply thorough district heating fueled by biomass and garbage.

Fig. 2.7 Main entrance of the New Karolinska Solna Hospital

- Heating system powered by heat pumps; the energy consumption of the hospital is meant to be less than 200 kWh/m^2.
- Use of innovative materials: copper has being limited and PVC was avoided.
- Double skin façade adopted to reach at the same time good energy and daylight performances.

Sum up

As learned from both literature and in situ analyses of the previous case studies, the project's scenario appears complex, mainly due to the relevance that healthcare structures have within their communities and to the diverse competences and interests involved. Analyzing and meeting the different stakeholders allowed to understand the extent to which a hospital can influence its community on a variety of subjects, from environment to economy, and on different levels, from the local to the national one. This allowed to identify the needs to be satisfied and the subsequent requirements to be fulfilled by the developed solution, keeping in mind the necessary trade-off among the various stakeholders' different positions.

The parallel study of the most outstanding sustainability best practices in different European healthcare structures and their comparison to the current average scenario, particularly in the Italian reality, enhanced the comprehension of the main criticalities and the identification of feasible solutions to improve hospital sustainability. Direct in-situ observations promoted the broadening of the multidisciplinary approach, which characterizes this project, and allowed to deeply understand how tightly the different sustainability areas are related to each other.

Interviews with designers, staff and patients helped instead to highlight the main factors that concur to hospital sustainability. Such concrete experiences have been extremely helpful in filling the gap between academic theory and actual hospital needs, leading to the identification of the best method through which to consider such a complex scenario, without simplifying it. Considering the diversity of the social, environmental and economic needs of the different stakeholders, together with their relevance and urgency, it is to conclude that a tool to evaluate the sustainability of a healthcare structure should be as simple as possible, applicable in short time, not requiring high additional expenses and, especially, should produce a specific outcome, capable of pointing out the best strategy for sustainability improvement.

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Chapter 3
Healthcare Sustainability Evaluation Systems

Maddalena Buffoli, Stefano Capolongo, Michela di Noia, Giulia Gherardi and Marco Gola

Abstract Many different evaluation systems are today available to assess buildings' performance. Concerning sustainability, especially of healthcare structures, the most widely recognized and commonly used systems are the American LEED, the British BREEAM and, within the Italian reality, the ITACA system; all of these are then surrounded by other minor management evaluation systems. So after a deep analysis of the state of the art, focusing in particular on the previously mentioned evaluation systems, it was possible to identify the main strengths and weaknesses of such tools with respect to the Sustainable Healthcare's project final objective. An interesting starting point is their hierarchic structure, employing a scoring system based on appropriately weighted credits. Undoubtedly though, these evaluating instruments focus on the built structure and its environmental impact, lacking in multidisciplinarity and in considering all the three spheres of sustainability, not including, for instance, neither user-centrality, health outcomes, nor managerial issues. The research analyses also the Joint Commission International accreditation, that works with healthcare organizations, governments and international advocates to promote rigorous standards of care and provide solutions for achieving peak performance. In fact, its goal is to improve the efficiency quality and safety in healthcare.

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Keywords LEED healthcare · BREEAM healthcare · ITACA · Joint commission international · Existing evaluation systems · New construction · Existing buildings · Sustainability

LEED Healthcare and LEED Existing Building, USA, 2009

The Leadership in Energy and Environmental Design (LEED) Healthcare system is a set of performance standards required for the certification of healthcare structures. Its goal is to promote healthful, durable, affordable and environmentally sound practices in building design and construction. This rating system is supported by the U.S. Green Building Council (U.S.G.B.C.), a nonprofit association that promotes and provides a comprehensive approach to sustainability.

There are different LEED programs depending on whether the object of evaluation is a new construction (USGBC 2009) or a restoration of an already existing building (USGBC 2011a), rather than specific types of buildings, such as hospitals (USGBC 2011b).

The main areas of evaluation are structured in: intent requirements, pre-requirements and potential technologies and strategies, and they include: *Sustainable Sites*, *Water Efficiency*, *Energy and Atmosphere*, *Materials and Resources*, *Indoor Environmental Quality*, *Innovation in-design* and *Regional Priority*. In particular, this last topic tries to provide an incentive to the acquirement of credits that address geographically specific environmental priorities, making the tool more flexible to the problem's boundary conditions. The system aims at evaluating the hospital in an objective way, particularly by means of quantitative data. More precisely, it evaluates 'design and construction activities for both new buildings and major renovations of existing buildings' (USGBC 2011a) and is organized in *macro-areas* and *credits*. Each credit is organized with a specific *intent* and its *requirements;* only in the LEED Existing Buildings there is a last component named *Potential Technologies and Strategies,* with possible solutions that can be applied to the project. Within the requirements, the various LEED systems offer different choice options: in particular the Existing Buildings system proposes an *Alternative Compliance Path for Projects Outside the U.S.*

Each credit has a total amount of points that can be assigned to each evaluation criterion; the criterion's achievable score is weighed according to its relevance and influence within the evaluating system. The final certification level depends on the range in which the global score achieved by the evaluated structure can be classified:

Certified	Silver	Gold	Platinum
40–49 points	50–59 points	60–79 points	≥80 points

It was observed that the credit *Optimize Energy Performance* has a relevant weight in the evaluation systems. Its score is given according to objective data with specific cases requiring further calculations to verify the results, referred to the requirements included in the credit. Most of the data are easily accessible and/or can be found on-site with specific measuring tools; other data, instead, requires the knowledge of specialized technicians, as for *Water Efficiency*.

The evaluation system does not have a weighing method for indicators, in fact all points reached in every area are added up together, reaching a total score that goes from 40 to 110. By the way, not every area has the same importance. The assessment can be done only by qualified personnel from LEED GBC.

Among all the interesting aspects that LEED Existing Building presents, two particularly noteworthy ones are, in *Building Reuse, Maintain Existing Walls, Floors and Roof* and *Maintain Existing Interior-Non structural*. These credits allow to extend the life-cycle of existing buildings, retain cultural resources, conserve resources, reduce waste and limit the environmental impact of buildings as far as materials manufacturing and transport are concerned. Moreover, the tool for Existing Buildings provides many details concerning *Sustainable Cleaning Equipment* for the maintenance of the building, while LEED Healthcare is very detailed regarding *Lighting* as a technical aspect to be differentiated among the different types of environments and users.

BREEAM Healthcare, UK, 2008

BREEAM (Building Research Establishment's Environmental Assessment Method) *Healthcare* evaluates the environmental performance of the building by studying its environmental impact's mitigation and its sustainability, also giving incentives on potential continuous improvements. BREEAM has nine scheme documents, which are specialized on different types of buildings such as hospitals, offices, courts, retails, prisons, etc.

The main areas of evaluation are: *Management* (concerning specifically building construction and maintenance), *Health and Well-being, Energy, Transport, Water, Materials, Waste, Land-use and Ecology, Pollution, Innovation* (BRE Global Ltd. 2010).

Although the tool mainly tends to evaluate environmental themes (energetic aspects are the ones that hold higher weight), there are also some aspects belonging to social sustainability. However, this system does not fit very well with the evaluation of an operative healthcare structure as it does not face some of its fundamentally relevant themes, such as those regarding participation and behavior within the structure (referring especially to themes like energy and security). Despite different *stages of assessment* (*design stage* and *post-construction stage*), the critical issue lies in how the evaluation system only takes into account the effects of an intervention with regard to the specific themes addressed, instead of inquiring different themes with the objective of understanding where the intervention would be more necessary. Furthermore, it considers quantitative data that does not take into account the opinion of the hospital users. The tool is not to be applied to existing buildings, but to design projects, concerning either a construction process or a renovation one. In particular in the *existing buildings fit-out* approach, the existing structure is taken into account only as an example to which compare future interventions. Moreover, BREEAM Healthcare specifies some kinds of healthcare facilities that can be evaluated through the instrument (e.g. general acute hospitals), and defines for each analyzed issue the differences in evaluation according to the kind of project (new construction or renovation). Furthermore, the buildings that do not fall within the BREEAM Healthcare scope can be evaluated using the other schemes or, alternatively, the BREEAM bespoke scheme.

The system is structured in weighted sections; each section includes the criteria through the ones credits are then assigned. The tool is precise, covers multiple issues according to the specific objective and type of evaluation and underlines the documentation required to verify the compliance of the building. The final score is given by the percentage of credits awarded in each section, multiplied by its own weight, where the categories *Energy*, *Health and Well-being*, *Management* and *Materials* have the highest weight.

The points from all sections are then added and the global evaluation is categorized as follows:

Pass (%)	Good (%)	Very good (%)	Excellent (%)	Outstanding (%)
≥30	≥45	≥55	≥70	≥85

ITACA Residential and Offices, Italy, 2004

Istituto per l'Innovazione e la Trasparenza degli Appalti e la Compatibilità Ambientale (ITACA 2011) is a set of performance standards for the development of qualified procedures for the promotion, spread and management of good practices in services supplies and public works, aiming to enhance urban and environmental sustainability.

It is an evaluation system focusing on the site of construction and on the building. Since a specific protocol regarding healthcare facilities does not exist, the tools referring to Residential and Offices categories have been analyzed as they can be considered similar to the hospital reality from some points of view (welcome, permanence, etc.). Its main areas of evaluation are: *Site selection*, *Resource consumption*, *Environmental loads*, *Interior quality* and *Quality of service*. The main focus of the scheme is therefore on environmental sustainability, with consumption of resources having the highest weight in both protocols' evaluation systems. Among the entries, particular relevance is given to the site, including its size and location with respect to the city. Moreover, this system highlights the importance of recovery and reuse of materials, as well as the presence of removable and replaceable materials. The tool appears thus inadequate for the evaluation of an operative healthcare structure also because some aspects are evaluated only through operative phases' forecasts, without actually investigating the actual situation (e.g. regarding emissions and solid waste). Finally, many fundamental aspects concerning an operative hospital structure are missing, such as the evaluation of artificial lighting.

This protocol is the most diffused assessment system in Italy and it has been approved by the Conference of Regions in 2004. In the same year the first release, including 70 indicators, has been published. Taking into account the need to diffuse the evaluation system and the issues concerning data gathering, a reduced version has been later developed, including only 28 indicators.

The instrument therefore evaluates in particular new constructions and restoration activities in operative buildings, with the validity of each criterion being defined for one or the other project typology. ITACA considers the building mainly as an object independent from its users and, unlike in the other analyzed instruments, the evaluation of users' involvement in the design phase is missing.

The ITACA system is organized by evaluation *areas*: these are subdivided into *categories,* which in turn are constituted by *criteria*. Each criterion is thus characterized by an area of evaluation, a category of belonging, an indicator of performance, requirements and a unit of measurement, together with an indication of the required calculating formulas, laws and references to be followed. Some criteria receive specific points for the presence of certain components, but the majority is based on data to be obtained or calculated. In this sense, the precision and level of detail of the tool is noticeable. It is important to underline how ITACA Offices performs the evaluation with regard to different conditions present in the structure, like the type of ventilation and air quality, and thus gives different scores in relation to the presence of natural and mechanical ventilation, or to the typology of the building (such as, for example, in case of the thermal transmittance's criterion). Furthermore, the weight of both protocols is basically equally divided between the areas of evaluation and their categories. The score ranges from −1 to 5, according to a scale of performance and to the method of verification reported in the descriptive sheet for each evaluation criterion:

Minimum acceptable performance	Improvement in performance	Best practice	Innovative/ experimental
≤0 points	≥1 point	≥3 points	5 points

The certification can be achieved with 2 points, in some regions volumetric incentives are given if more than 2 points are achieved by the assessed project.

JCI, Illinois, 1994

Created in 1994 by the Joint Commission International, this accreditation has a presence in more than 90 countries. As stated in the JCI official website, JCI works with healthcare organizations governments and international advocates to promote rigorous standards of care and provide solutions for achieving peak performance (Joint Commission International 2010). The goal of JCI is particularly important in the present world where improving efficiency quality and safety in healthcare has become a worldwide imperative. One of the main strengths of JCI is that it is compatible with government policy for upgrading the medical industry and necessary to strengthen compatibility with foreign hospitals. Given the need of healthcare providers to keep pace with globalization, what just stated is an important aspect. In fact, being accredited by JCI means that the medical services provided by a hospital are equivalent in quality and patient safety to medical services internationally. It also means that the hospital is reliable in treating patients according to international policies and regulations. The JCI system of accreditation appears very simple to understand and transparent in the way the institution is evaluated.

Furthermore, the research revealed that, thanks to its focus on the highest patient care standards and results-oriented process, JCI has earned the respect of most health care leaders. For this reason, WHO partnered with JCI and the Joint Commission to establish the first WHO Collaborating Centre for Patient Safety Solutions. In June 2011, JCI received four-year accreditation by the International Society for Quality in Health Care (ISQua). Accreditation by ISQua provides assurance that the standard trainings and processes used by JCI to survey the performance of healthcare organizations meet the highest international benchmarks for accreditation entities.

Findings

The existing evaluation systems aim to evaluate the structure of the hospital and the presence of certain technical, design and system aspects. One of the most evident criticalities of these systems is their excessive focus on the environmental and landscape sustainability, as opposed to their lack of depth in the economic and social aspects affecting the hospital system.

These are design tools and not performance measurement tools and they are also non climate-specific, although the newest versions aim to partially address this weakness. Moreover this kind of certification systems were developed and continuously modified by experts in green architecture and smart cities issues; some criticisms suggest though that these rating systems are not sensitive and do not vary enough with regard to local environmental conditions.

They are born as guidelines for the good design of a hospital building but are missing those features required to evaluate existing hospitals and not only as far as renovation and restructuring activities are concerned. These conditions do not allow to evaluate an existing building and to identify its weaknesses: the evaluation system can therefore not be used as an improvement instrument. Moreover, they mainly assess quantitative data; when qualitative aspects are considered, they are taken into account only from the point of view of the evaluator, without analyzing the users' perspective, which is instead fundamental in the hospital reality. Further unconsidered aspects include users' participation and involvement, presence of directions and health outcomes. The evaluation of the sustainability of an operative hospital cannot prescind from the assessment of its service quality, which relies both on managerial and structural factors. As far as the possibility to evaluate healthcare services management through a set of indicators is concerned, examples such as those purposed by WHO, EHCI (European Health Consumer Index), OECD and JCI should be considered. Apart from the last one, these systems are related to health and healthcare systems and consider a large number of quantitative indicators. JCI standards, instead, deal with hospital accreditation and assess many different qualitative factors. So, in different ways, these systems evaluate quality, positivity and sustainability of the offered services by analyzing both managerial strategies and their health outcomes.

The existing evaluation systems could therefore be improved by adding new features, specific for healthcare structures, to allow a global sustainability assessment capable of including not only environmental, but also social and economic sustainability. An innovative tool should thus enable the identification of critical areas to be improved, by taking into account a multiplicity of visions, which is essential in complex realities.

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Chapter 4
A Multidisciplinary Sustainability Evaluation System for Operative and In-Design Hospitals

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Abstract The Sustainable Healthcare project developed an original multidisciplinary evaluation tool, specifically designed to assess and improve a hospital's global sustainability by considering together the environmental, social and economic issues, so to give a comprehensive evaluation of the hospital, according to an appropriate concept of sustainability. The system, which aimed to be simple, light and easy-to-use, includes the main weighting to enhance sustainability, organized in a hierarchical way: specific indicators are contained in a series of criteria, which represent the most critical factors and the most effective starting points for hospital's sustainability improvement. They are finally divided into the three macro-areas of sustainability: social, economic and environmental sustainability. In order to take

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into account the different interrelationships among the various components of the system, a weighting process was carried out according to the Analytic Network Process method by Saaty in 2005. This allowed to take into consideration different users' points of view and, most importantly, the human factor, thanks to the development of a weighting system based on the opinions of specific focus groups, which included experts and professionals from different healthcare sectors. The evaluation system's application to a hospital allows the structure's global sustainability to be assessed.

Keywords ANP · Susthealth evaluation system · Macro-areas · Criteria · Indicators · Focus groups · Interviews · Economic sustainability · Social sustainability · Environmental sustainability

System Structure

The problem of promoting sustainability in hospitals and creating a new model to be used as reference for new realizations was also analysed by prof. U. Veronesi (Capolongo 2001), with a commission directed by arch. R. Piano, who stated 10 principles that should inspire the hospital of the future, considering mainly the social sphere and partially the environmental sphere, but not taking into account the economic field. In particular, the themes of patients' comfort, the correct position of the building inside the urban context, the medical staff-patients relationship, the perception of sense of belonging and solidarity inside the hospital and a good and efficient organization (in terms of effective diagnosis therapy and rehabilitation) are emphasized. Moreover, attention is focused on the adequacy of the technologies (plants and medical appliances), the flexibility of the system building-plant for future improvements and the role of the hospital as a research center.

Regarding operative hospitals, in many countries a considerable part of the healthcare system is made up by structures, which date back to several years ago. For instance in the northern Italian region of Lombardy, almost 45 % of the hospitals are more than 65 years old (Capolongo 2006). Decades ago they were built according to regulations, typologies of medical treatments, technological possibilities and community's needs which deeply differ from the current ones, and with no hint about neither flexibility nor sustainability. Nevertheless such hospitals are often operative and largely used, as they can still accomplish their main duties and give a contribution to the local community. Even though a new sustainably designed hospital would work better, adding more value and with fewer drawbacks for the community and the environment, its construction would be very expensive (even more if added to the demolition of the old one) and, most of all, controversial. The construction of a new hospital is indeed a matter of public concern, involving numerous stakeholders with different (sometimes opposite) interests which, as taught by prof. (Dente 2011), will be settled only with proper strategies and long time frames, after which success, intended as the building of the new healthcare structure, is still not guaranteed. Moreover, many years will pass between the design, the construction and the functioning phase, turning a modern project into an old-fashioned one, despite its initial innovativeness and flexibility. Changing times and changing needs therefore continuously hinder true sustainability once the hospital becomes operative.

The aim of this project has been to develop a solution that could improve hospitals' sustainability while they are operating, independently from how old they are. Though the Piano–Veronesi Hospital concept (Capolongo 2001), the realization of a blueprint of a sustainable hospital is not suitable to deal with issues concerning existing hospitals since it requires a global and abstract vision which cannot easily fits the constraints given by existing structures and which is unlikely to propose concrete and readily viable solutions. Therefore the possibility of identifying sound, scientifically-based guidelines to the realization of sustainable hospitals from existing ones was analyzed. This kind of tool can be useful, but limiting and limited according to different points of view, mainly due to the fact that it is impossible to point out best practices, which could fit to every context. Best solutions could deeply differ depending on local environment, on climate, on mix and size of the served community, on available resources and on the starting point, with a best practice example for a certain case being negative for another one. The need for a tool capable of giving case-specific results, also if employed by non-experts, thus clearly arises.

The new tool has to be easy-to-use and able to propose and foster specific solutions to improve sustainability in operative hospitals that, for economic, structural and functioning reasons, cannot undergo radical renovations. Moreover, the identified solutions should be as effective and low cost as possible. So an innovative, multidisciplinary, scientifically-based evaluation system has been developed to allow the study of case-specific solutions, including the blueprint's and guidelines' advantages, while overcoming their limits. According to the previously mentioned features, the components of the system, i.e. the identified indicators should themselves include some solution proposals and be SMART: *Specific*, *Measurable*, *Attainable*, *Relevant* and *Timely* (Doran 1981). Moreover the indicators should be *upgradable*, in order to fit to future technologies and regulations, *clear* and *easy-to-use* so that their evaluation will neither allow ambiguities nor require excessive efforts in terms of time and human resources.

These indicators' specifications will also belong to the whole system by transitive property. Thanks to the given tool it would therefore be possible for each healthcare structure to evaluate itself, to identify the areas of most effective intervention and to develop specific sustainability plans, based on the elementary suggestions that could be found in the criteria's definitions.

Structure Definition

The sustainability of a healthcare structure should be determined considering its three principal dimensions: economic, environmental and social. The Sustainable Healthcare evaluating system is implemented bottom-up: the basis of the pyramid is formed by these fundamental and interconnected *macro-areas* (Buffoli et al. 2013). Each of these areas is evaluated through a hierarchic framework of C&I

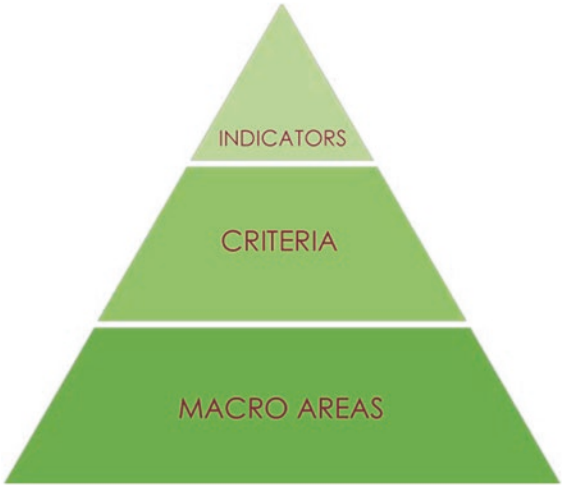

Fig. 4.1 Hierarchical organization

type: *criteria* and *indicators*. This framework is used by many government agencies, non-governmental organizations and academic researchers to define sustainability monitoring and evaluating programs (Wright et al. 2012). The macro-areas have different relevance in the evaluation system according to the importance and the impact they hold on the sustainability of an operative healthcare structure or an in-design hospital (Fig. 4.1).

The macro-areas are evaluated through different *criteria*, which are the elements concurring to the sustainability of the specific aspect. Each criterion relates to one key macro-area of sustainability, and may be described by one or more *indicators*. The hospital performance, concerning the specific criterion, is given by direct information obtained through the indicators' evaluation. According to the definition of the standard UNI 11097 an indicator is:

> The qualitative or quantitative information that is able to evaluate its change during the time and to verify the defined quality goals, in order to take the correct decisions and choices. (Ente Nazionale Italiano di Unificazione 2003).

The identified indicators therefore not only allow to compare different operative or in-design healthcare structures, but also to evaluate how the performances of those specific hospitals subject to evaluation are changing over time, thanks to the indicators' periodical measurements. The objective is to define a balanced assessment tool useful to find the most affordable solutions for a project proposal and understand possible lacks in hospital structures and services in order to improve them. The system therefore can help the choice among different alternatives and suggest corrections to increase the sustainability of the chosen one.

Since the object of study is a hospital, the indicators should be able to describe its actual current situation, related to the specific year of evaluation. They are either quantitative or qualitative: e.g. the evaluation of the flux of resources is made according to quantitative data, while questionnaires to evaluate and improve the social macro-area give qualitative information which is then quantified and classified. The assessed hospital obtains a quantitative result for each criterion; the score relative to each macro-areas is then obtained by summing the criteria's results according to the multi-criteria decision model. The score assigned to the criteria is computed thanks to the ANP method (see next paragraph), by aggregating information from various indicators.

Sometimes criteria do not have indicators and in this case the assessment is directly made at the criterion level; this happens because the issue tackled by the criterion is sufficiently specified and does not need to be further divided.

The achievement of a certain score for a selected criterion requires the fulfillment of compulsory *pre-requirements*. If they are not met, the specific criterion cannot be scored since these pre-requirements represent the minimum standard requested to an operative healthcare structure, in terms of aspects ranging from the economic, social and environmental points of view, such as technology standards or compliance to laws and regulations. It can occur though that local and national regulations are not fulfilled, because of exemptions from which the hospital can benefit.

The differences occurring in the analysis of an operative hospital or of an in-design structure bring to an ad hoc allocation of different reference values. In the case of existing hospitals the following indicators and criteria are not included: *Materials and Resources*, *Risk* and *Site physics* indicators in *Urban Planning*, *Construction Waste* in *Wastecare*, *Building Equipment* in *Watercare*, *Constructive Technology* and *Passive and Active Technologies* in *Envelope Technologies* and *Build in Quality Process* in *Managerial Waste* (Buffoli et al. 2014b).

As far as the *Materials and Resources* criterion is concerned, the choice is due to the great importance that the selection of materials has on environmental performance of the building under construction. This situation does not occur in the building already built, where this condition cannot be changed and where the environmental impact of the employed materials is already settled.

The indicators relating to the location and design of the hospital's outer area cannot be addressed in the evaluation of existing hospitals as they relate to policy choices. The policies are developed in the early stages of the design of a hospital and cannot be modified. Their importance, instead, is relevant in the case of new design hospitals.

Build in quality process is specific of the sustainable in-design hospitals system. It assesses the cost-effectiveness of the design phase with respect to the achievement of certain performance, highlighting the propensity for innovation. This one is characteristic of the design phase, while it is not relevant in the assessment of operative hospitals. In the in-design hospital evaluation system, instead, are not present the *Lean process* indicator in *Managerial Waste*, *EducInformation* in *Saving with Efficiency*, *Waste Generation* and *Hazardous Waste* in *Wastecare*. In fact they are intrinsic factors of the operative hospitals (Figs. 4.2 and 4.3).

The scores for each macro-area show the performance of the hospital in each domain of sustainability. These scores are added up according to their relevance to give the final score on the overall performance of the hospital as far as sustainability is concerned.

The assessment of criteria and indicators is developed through a series of evaluation forms where many features, aims and evaluation methods are considered (Bottero 2011). For each criterion the forms represent:

- **Pre-requirements**: it is an optional feature, pre-requirements are listed just for some criteria. Pre-requirements are usually related to the satisfaction of standard requirements or to the presence of specific elements needed to produce the performance measured by the criterion. If a pre-requirement is not met it is impossible to evaluate the criterion; sustainability points cannot be attributed if a hospital does not even satisfy the minimum standard requirements.
- **Definition**: it is a description of the criterion in a clear and shareable way.
- **Aim**: it explains the strategy encouraged by the criterion and so the expected output.
- **Description**: it defines the evaluation rules and the indicators which form the criterion, as well as the employed aggregation method.

As far as indicators are concerned, forms are organized in this way:

- **Definition**: as for the criterion a shared description of the indicators is presented.
- **Aim**: also in this case the desired output is cited to highlight the encouraged development strategy.
- **Description**: it indicates the method to evaluate the indicator and so the thresholds used to give credits.
- **Unit**: it defines the units of measurement for each assessed performance.
- **Time reference**: it states the application mode of each indicator; some can be assessed once or in different design steps, particularly if a new assessment is needed in the changing of framework condition.
- **Initial data availability**: it defines the data sources needed to carry out the assessment.

Score Evaluation

The *Indicators* are the first step of the whole evaluation system since they directly measure the hospital's performances. By means of questionnaires, interviews or quantitative evaluation a score ranging from 0 (worst performance) to 5 (best-in-class) is assigned to each indicator. As far as those indicators based on a direct evaluation of the users' (hospital users include not only patients, but also staff and visitors) satisfaction and opinion, the maximum score is assigned if a high percentage of the interviewees give positive answers, with the obtained score then decreasing together with the users' satisfaction. Indicators that are evaluated through interviews or quantitative measurements obtain instead points in a cumulative or progressive way. As far as the first method is concerned, the indicator's

Fig. 4.2 Global SustHealth system for operative hospital according to the structure of the macro-areas, criteria and indicators

total score is given by the sum of the points assigned if different technologies/ solutions are adopted. Concerning the second one, the score obtained implies the compliance to the previous requirements belonging to the indicator, which are given in ascending order.

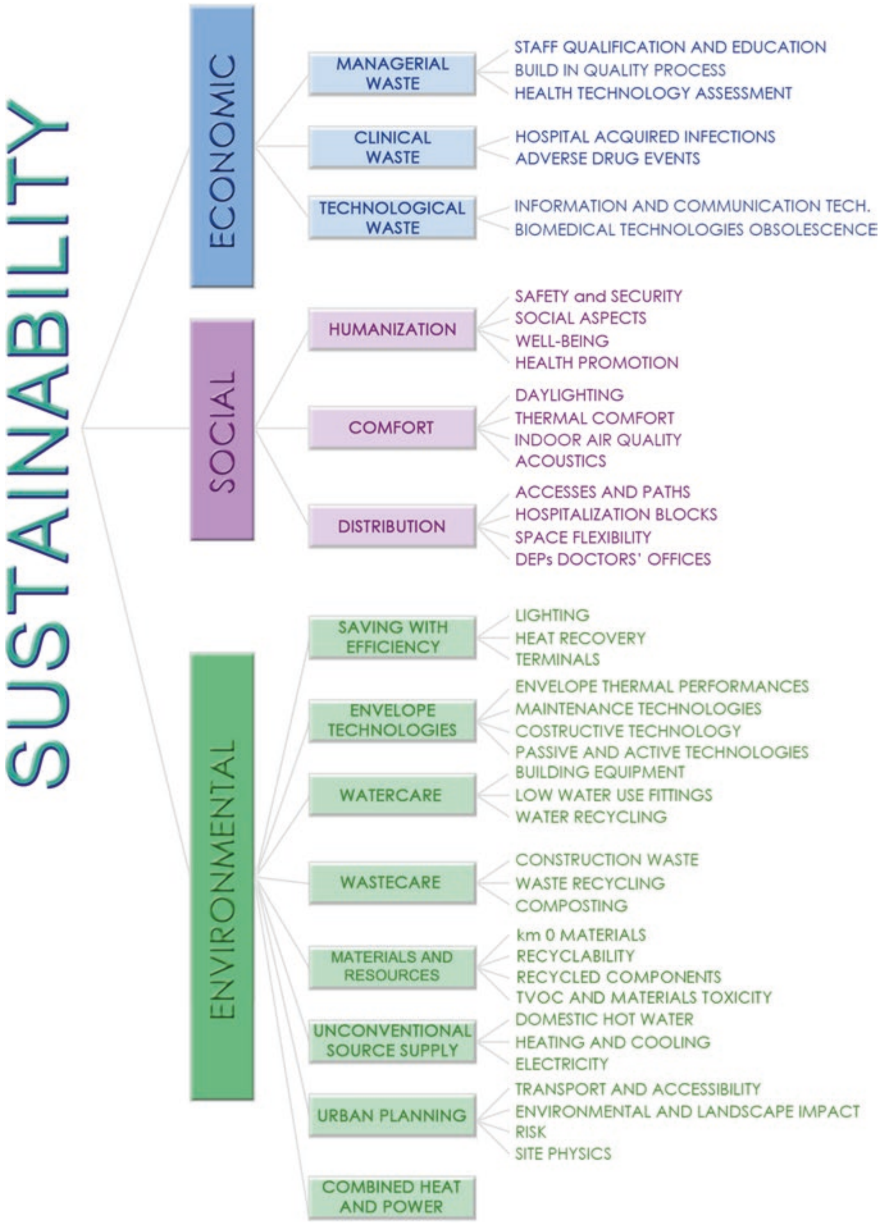

Fig. 4.3 Global SustHealth system for in-design hospital according to the structure of the macro-areas criteria and indicators

Indicators though are just at the top of the hierarchical scale that forms the evaluation method of this study. The scores obtained in the different indicators are then used to evaluate the *criteria*, that then concur to define the sustainability performance in the three macro-areas.

The criteria's obtainable points range from 0 to 100 and are given through a weighting system that quantifies the importance of those indicators constituting the specific criterion. Furthermore, even if all the indicators of a criterion obtain a positive score, failure to satisfy one of the specified pre-requirements entails the non evaluation of the specific criterion meaning zero points for it.

Referring back to the example made in the previous paragraph, the evaluation method for the *Comfort* criterion is expressed below:

$$Comfort = \frac{a * IAQ + b * Lighting + c * Acoustic + d * Thermal}{5}$$

where:

$$a + b + c + d = 100$$

On a similar basis, the weighting system is used to define the scores obtained in the different sustainability macro-areas by assigning different levels of importance to the various criteria.

Following the previously illustrated example, the evaluation method for the Social Sustainability area is described below:

$$Social\ sustainability = e * Humanization + f * Distribution + g * Comfort$$

where:

$$e + f + g = 1$$

To finally define the global sustainability of an existent or in-design hospital the points obtained in the three macro-areas are weighted according to the following formula:

$$SustHealth = A * social\ s. + B * economic\ s. + C * environmental\ s.$$

where:

$$A + B + C = 1$$

As a result, global sustainability is defined with a score ranging from 0 to 100. The hospital object of evaluation is then comparable with other hospitals and its performance evolution can be determined by analyzing score obtained in different years.

In this perspective, a correct evaluation of the healthcare structures' sustainability requires a coherent and consistent definition of different weights for each level (*indicators, criteria, macro-areas*). The Analytic Network Process (ANP) is the method used in this study to define the employed weighting system. ANP is a generalization of the Analytic Hierarchy Process (AHP), since it allows to consider the dependence and interaction between the elements of the hierarchy. The main characteristics of the method are briefly described below; for its complete theory, refer to (Saaty 2005).

To evaluate priorities among different *indicators/criteria/macro-areas*, opinions are gathered by means of pairwise comparisons: verbal preferences are then converted into numerical coefficients through to the *Fundamental Scale* given in Table 4.1.

The scale represents the points to be assigned when comparing A to B. If inverse comparison is done, B with A, reciprocals are used. The vector obtained through

Table 4.1 Saaty's scale used to convert verbal statements into numerical preferences

Saaty's fundamental scale	
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2 4 6 8	Intermediate values

assigned priorities works as the principal eigenvector of the matrix network. The inconsistency concept, which is strongly related to that of the matrix network, then requires the inclusion of an inconsistency index through which the pairwise comparison's consistency is evaluated. Saaty suggests a maximum inconsistency level of 10 % (inconsistency is judged as a fundamental part of the ANP method, since, when different from zero, it implies a non conventional way to assign preferences) (Saaty and Ozdemir 2008). Differently from hierarchy, ANP considers a network mode of clusters of elements that can be connected to entities either in another cluster (*outer dependence*) or in the same one (*inner dependence*). Such a configuration fits well to the purpose of the study since it allows to consider the relations between criteria belonging to different areas of sustainability, the so-called *outer dependence*.

In Fig. 4.4 the ANP model network to define weights of macro-areas and criteria is shown. Arches from different areas indicate outer dependences; a loop in a component indicates inner dependence. Priorities calculated from pairwise comparisons form the so-called *supermatrix* and are used by the software to give the results of the weighting method.

A coherent evaluation of the weights in the three macro-areas requires the constitution of a high skilled team, formed by different experts both from the fields of healthcare structures planning and management. The focus group was formed by leading academic experts in the hospital architecture and management fields, together with experienced professionals coming from the healthcare environment. The focus group's direct knowledge about healthcare structures problems allowed to define the main and most effective areas for intervention. The inspiring philosophy on which the weighting system is based concentrates on those aspects that ensure better performance of the existent hospital with the less invasive *structural changes* (structural refers to significant architectural, technical and managerial changes) and the best practices for the in-designing hospitals.

A deeper analysis of the criteria's weights within a specific macro-area and of the indicators' weights inside a criterion required contribution from experts (at least three per each different weight definition) on the different subjects considered in the hospital evaluation both in existing operative structures and in-design ones. Once again the experts involved in weights' definition came from both the academic and professional field.

Results obtained from pairwise comparisons were elaborated with *Superdecision*: Fig. 4.5 shows examples of implementation phase of the software.

In the following pages are reported all the weighing systems referred to the macro-areas, criteria and indicators, respectively for the existing operative hospitals and the in-design ones (Figs. 4.6 and 4.7).

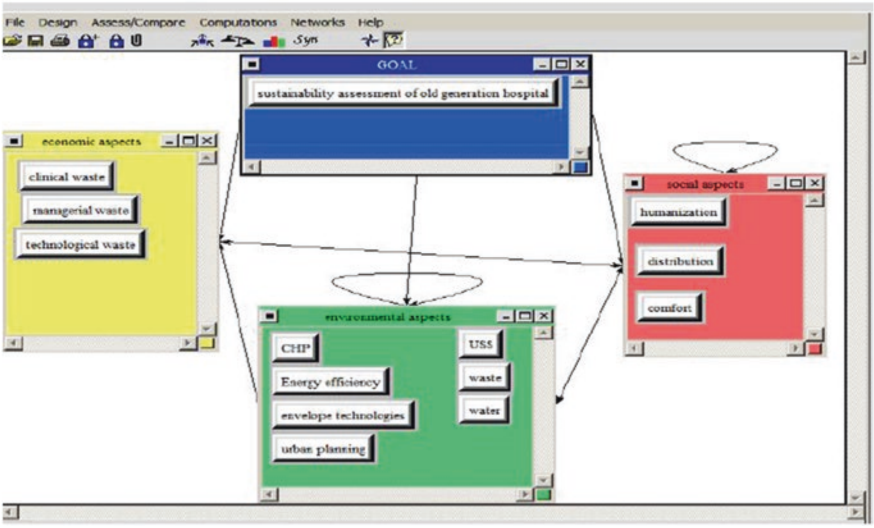

Fig. 4.4 Clusters and nodes of the model to establish the weighing system for operative hospitals' sustainability

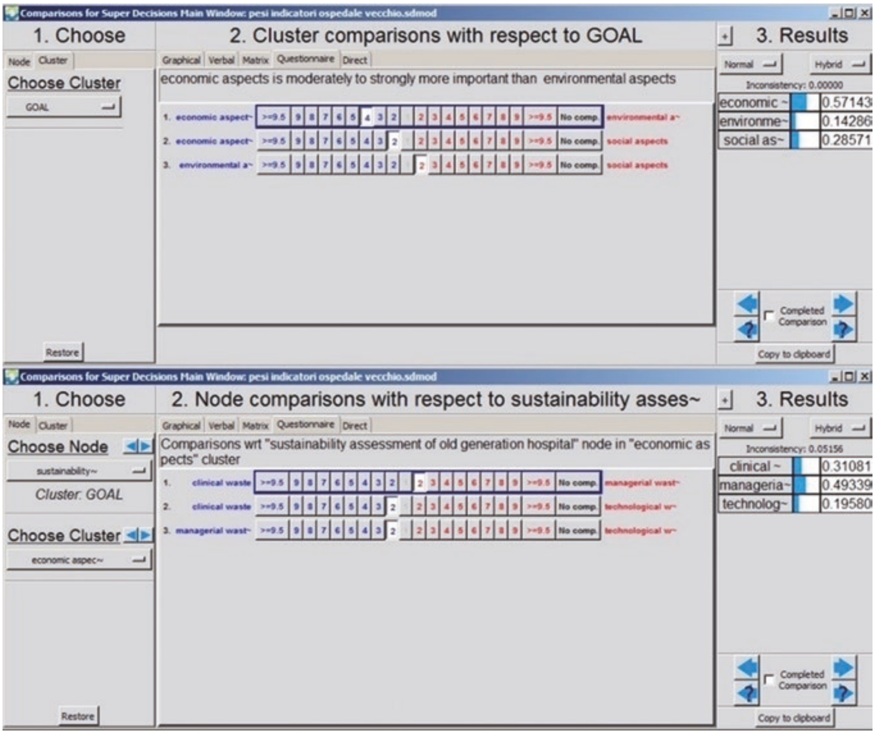

Fig. 4.5 *Superdecision* software implementation

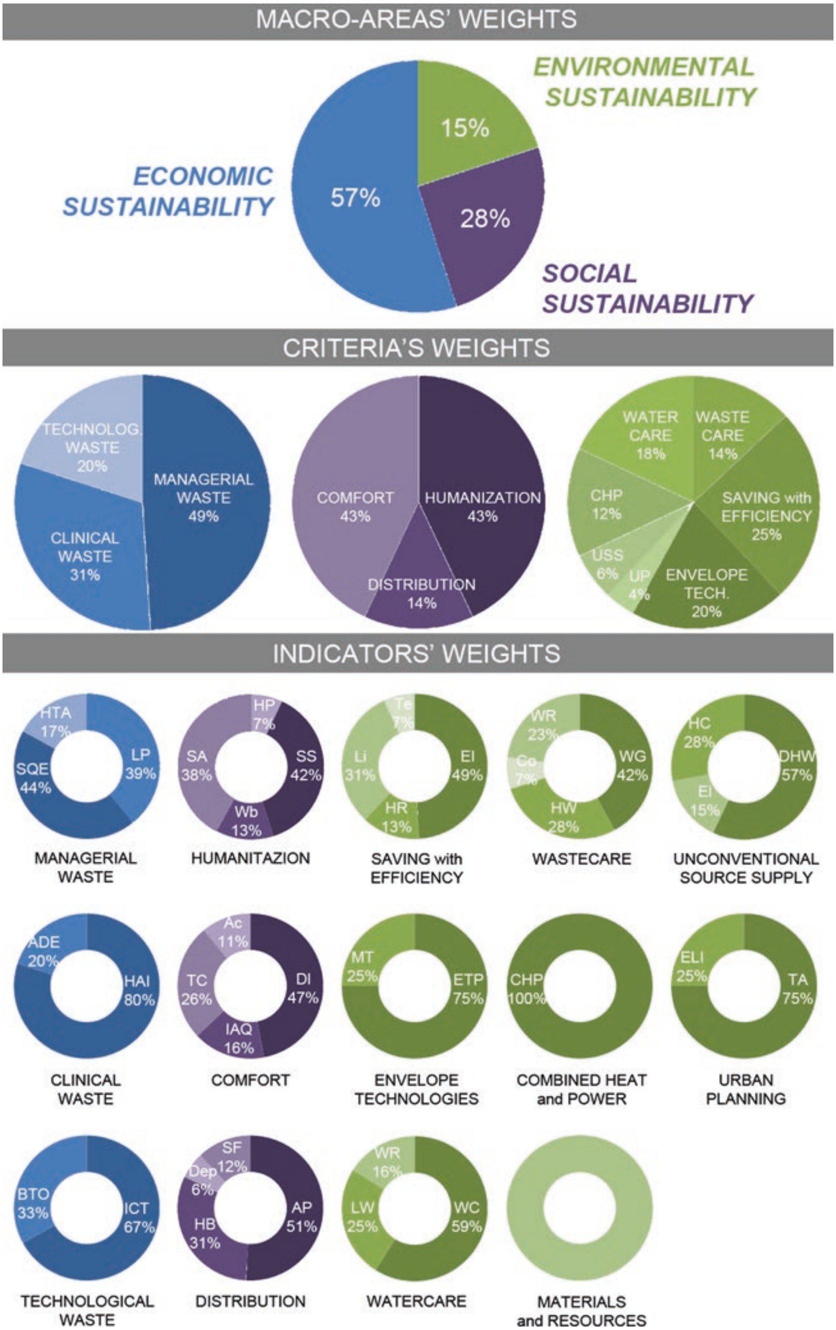

Fig. 4.6 Weighing system for operative hospitals referred to macro-areas, criteria and indicators

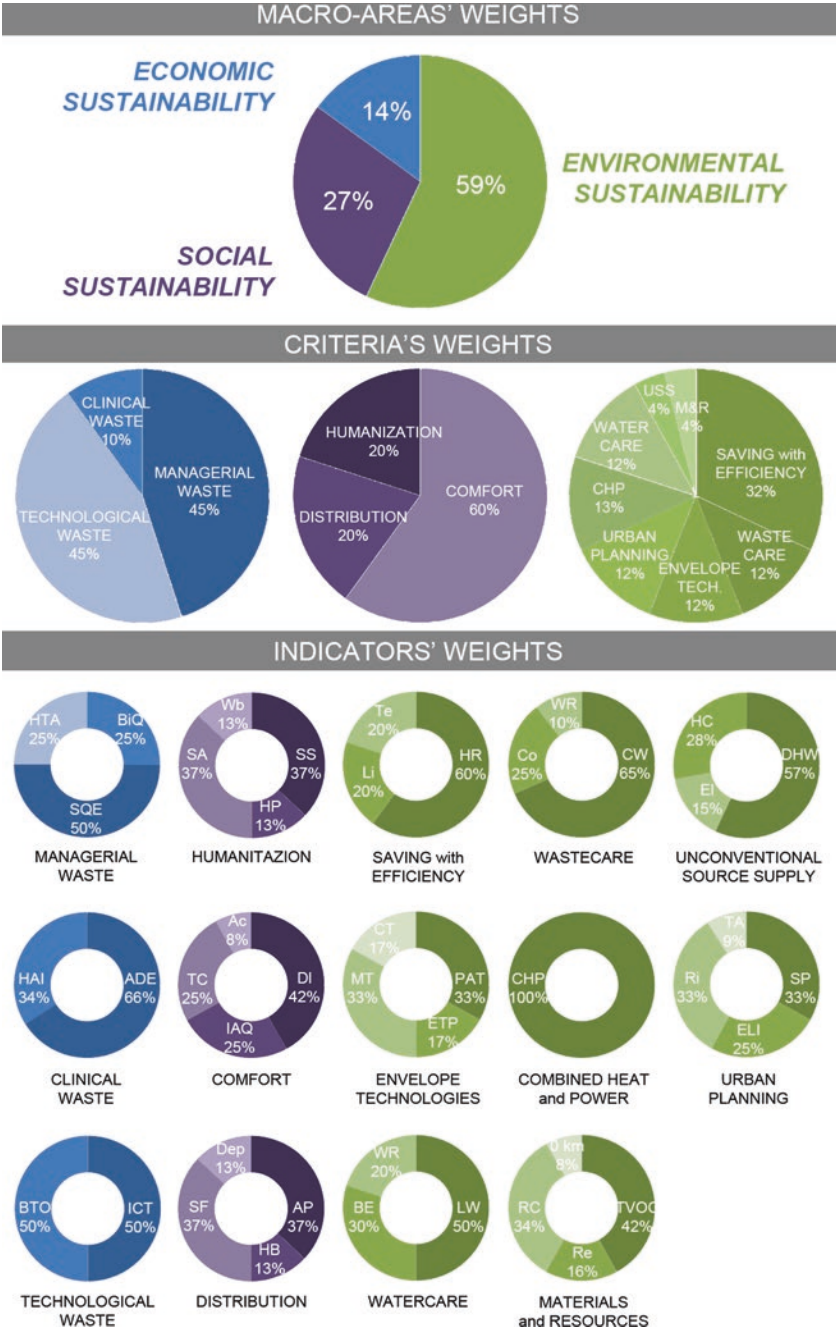

Fig. 4.7 Weighing system for indesigning hospitals referred to macro-areas, criteria and indicators

Economic Sustainability[1]

Few would contest that despite it is not the first goal for a healthcare system, its *Economic Sustainability* is necessary to assure the capability to deliver safe, high-quality healthcare services to patients and citizens of both the present and the future generations. The capability of being sustainable from an economic perspective becomes even more urgent in periods of crisis as today, since it deeply affects its country's economy (Young 2006). This capability is the result of efforts paid at the different levels within the healthcare system, ranging from macro-level to micro-level decisions. In this chapter, our attention is focused to healthcare providers and to their capability to do more with less. Each single healthcare organization has to cope with increasing demands from patients/citizens for safe, high-quality services as well as with shrinking economic, human and environmental resources.

In this regards, healthcare managers have the ethical responsibility to design and implement strategies and initiatives aimed at improving the capability of the organization to do deliver societal value efficiently. This capability is affected significantly from managerial, technological and clinical factors. With respect to management, the research focused on three key managerial practices that are diffusing nowadays in healthcare organizations aiming at providing managers and professionals with clear guidelines to improve service quality and achieve savings. They are: Health Technology Assessment, Lean Process implementation in the work flow, and staff qualification and education. Concerning clinical issues, the research group analyzed the capability of the healthcare organization to cope adequately with some specific, relevant adverse events. This leaded to take into account facilities appropriateness, procedures correctness and quality of the delivered service at one time, also including health outcomes and the consequently related expenses. Finally, technological solutions implemented by the healthcare organization are comprised in the evaluation as indicators of modernity and tools to facilitate and improve healthcare services delivery, saving time, money and environmental resources.

MANAGERIAL WASTE

Pre-requirements (only for operative hospitals)

- **Budget respect**: the hospital structure's actual expenses do not exceed the originally defined by more than 20 % meaning it adequately manages and allocates its financial resources limiting wastes.

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Health technology assessment (HTA): presence of (or consultancy from) a HTA and/or clinical engineering unit and/or of a technical office able to deal with technical requirements of biomedical technologies and to consider correlated economic and clinical aspects.

Definition
The criterion evaluates the adoption or design of proper management strategies, which are the basis for the hospital functioning and allow to increase the provided services' effectiveness and efficiency, minimizing waste and optimizing resources allocation.

Aim
To improve the appropriateness of the healthcare structure's management strategies, in order to minimize waste, optimize workflows and improve service quality.

Description
The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7).

$$\text{Managerial Waste} = \frac{(x \cdot SQE + y \cdot LP + z \cdot BiQ + w \cdot HTA)}{5}$$

where

SQE	Staff Qualification and Education
LP	Lean Process (only for operative hospitals)
BiQ	Build in Quality process (only for in-design hospitals)
HTA	Health Technology Assessment

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MANAGERIAL WASTE—staff qualification and education

Definition
This indicator measures the staff qualification and education level.

Aim
The indicator aims to provide recommendation in terms of creating an appropriate staff mix in line with the hospital needs and European standards. It also evaluates staff qualification and education level of pertinence together with staff involvement in improving working processes.

Description

Scores are assigned based on:

SCORE	STAFF QUALIFICATION and EDUCATION
1	A pertinent staffing plan has been developed, based on the structure needs and on the recommendations from department and service directors. To be defined as pertinent, the staffing plan should be in line with the European standards of hospital's workforce: n° of physicians and density (per 10,000 population); nursing and midwifery personnel and density (per 10,000); health management and support workers density (per 1,000)
+1	Physicians, nurses and staff are involved in the organization's quality improvement activities of the hospital
+1	The health organization has an effective process for gathering, verifying and evaluating the candidates' credentials (license education training competence and experience). All the activities related to recruiting evaluating and appointing candidates are accomplished through a coordinated efficient and uniform process for the following staff categories: medical staff permitted to provide patient care without supervision; nurse staff; other health professional staff members
+1	The hospital involves the staff in educating and training their colleagues. The employees are allowed, for example, to develop teaching materials and courses to divulgate their expertise and knowledge
+1	The healthcare organization provides staff with opportunities to learn and advance personally and professionally. Thus, in-service education and other learning opportunities are offered to the staff

Unit

[–].

Time reference

Carried out once during planning phase, then annual follow-up.

Initial data availability

National Classification of Healthcare Structures (if available); data provided by the Board of Heath; hospitals documents; surveys.

MANAGERIAL WASTE—lean process—only for operative hospitals

Definition

This indicator evaluates a hospital structure's ability to organize its activities in such a way to maximize the efficiency of its most important and costly resources: people.

Aim

The indicator aims to obtain detailed information on the existing proportion between added value and non-added value activities and how this impacts the different types of human resources and in what wards these criticalities are most frequent.

Description

The following steps allow to implement the process required to recognize and quantify the activities which do not provide added value in terms of health services, to prioritize areas of intervention and to obtain effective results in terms of increasing the structure's productivity without increasing its operating costs (efficiency increase):

1. Understanding of the economic and operational differences between the different types of human resources (doctors staff nurses etc.):
   (a) Definition of the different staff categories and of their job descriptions, which allows to clearly differentiate roles and tasks avoiding risky overlapping or inappropriate activities
   (b) Knowledge of the average cost per hour for the different staff categories enabling a careful prioritization of the areas of intervention
   (c) Distinguish and define for the different types of human resources (doctors staff nurses etc.) those activities that add value (VAA—Value Added Activities) and those which do not add value (NVAA—Non Value Added Activities). It is important to understand that the same activity can be classified differently according to what human resource carries it out. For example:
      - Doctors: Visits (VAA); Writing/Moving (NVAA);
      - Nurses: Work on patients (VAA); Writing/moving patients (NVAA);
2. Observe the employees' activities and create a map of the proportion between VAA and NVAA;
3. Quantify the losses due to NVAA and stratify them (per ward per type of employee etc.) and prioritize the areas of intervention;
4. Redesign the structure's activities processes and maybe even organization to increase the level of VAA;
5. Return to point 2.

These 5 steps must first be applied to the most critical wards and then eventually expanded to all other wards. The expansion percentage will be calculated as the ration between 'attacked' wards and total wards.

Indicators' variables (to be measured to obtain the final score):

- depth of application (step reached in the model ward in terms of percentage);
- level of expansion (percentage of wards where the approach has been deployed);

The indicator score is given by the product of the two variables.

$$LP = (\%\ depth\ of\ application) * (\%\ level\ of\ expansion)$$

SCORE	LEAN PROCESS (%)
1	0 < 20
2	20–40
3	40–60
4	60–80
5	80–100

Unit
[%].

Time reference
Quarterly survey.

Initial data availability
Cost per hour of the different types of human resources to be obtained from the finance department.

MANAGERIAL WASTE—built in quality process—only for in-design hospitals

Definition
This indicator evaluates the quality of a hospital's design/planning process by evaluating the level of benchmark activity carried out.

Aim
It aims to encourage a culture where different benchmarks are applied in designing new hospitals. It also wishes to develop a widespread understanding of how the principles behind benchmarks need to be adapted to the scenario in which the building is located with its different opportunities and restrictions especially from the economic point of view.

Description
Scores are assigned based on:

SCORE	BUILT in QUALITY PROCESS
1	The project team (PT) has carried out extensive research on which are the existing European best in class structures as far as different macro-areas are concerned but was not able to apply any best practice to its structure
+1	The PT has understood the principles which characterize the identified best practices and has applied an adapted version of these best practices to at least one macro-area
+1	The PT has applied an adapted version of the identified best practices to at least 50 % of its structure's macro-areas
+1	The PT has applied an adapted version of the identified best practices to at least 100 % of its structure's macro-areas
+1	The PT has developed at least one solution that has been internationally recognized as a new best practice

Unit
[–].

Time reference
Carried out once at the end of the project.

Initial data availability
Final forecasted budget of the hospital building project and actual list of expenses carried out to complete the hospital. Benchmark identification for each hospital macro-area must be considered during the design/planning phase is usually defined on a European level.

MANAGERIAL WASTE—health technology assessment

Definition
The indicator evaluates the Health Technology Assessment (HTA) analysis process and its ability to satisfy the hospital's requirement concerning equipment's safety and risk, effectiveness, flexibility, indication for use, costs, costs/benefits ratio and its social and ethical implications.

Aim
To improve the use of a simple and effective tool, such as HTA, to support decisional processes, in order to reduce healthcare costs according to evidence based medicine and to supply the hospital with appropriate technological equipment according to the population's characteristics and to the social and healthcare standards in the area.

Description
The indicator evaluates the relevance and quality of the activity carried out or planned by a multidisciplinary unit for technology assessment, considering HTA's completeness and consistency with respect to international guidelines.
Scores are assigned through the analysis of the entries enquired by the applied or planned HTA process, according to their significance and spread within the common practice.

SCORE max. +1.5	Clinical evaluation	SCORE max. +0.75	Scientific evaluation
+0.23	Clinical results and benefits	+0.16	Effectiveness efficiency
+0.18	Impact on quality of life (social, work, ect.)	+0.14	Acceptance satisfaction of patients/relatives
+0.23	Potential adverse events	+0.15	Technology's performances
+0.18	Ethical and psychological implications	+0.14	Managerial changes and inertia to change
+0.18	Acceptance and satisfaction of patient's relatives	+0.16	Costs/benefits costs/effectiveness ratio

SCORE max. +1	Technical evaluation	SCORE max. +0.75	Managerial evaluation
+0.2	Indication for use	+0.16	Work flow's changes
+0.2	Proposal motivation	+0.1	Roles' and skills' changes
+0.1	supplier's reputation	+0.16	Implication on education and organization
+0.1	Future updates	+0.13	Period of transition
+0.2	Alternative technologies	+0.1	Changes in the relationships among departments
+0.1	Institutions which suggest its adoption	+0.1	Changes in the relationships with other hospitals and healthcare structures
+0.1	Department's priority		

SCORE max. +1	Economic evaluation
+0.15	Initial costs
+0.13	Activity in terms of patients and case-mix
+0.12	Return on image benefits
+0.15	Expected revenues
+0.15	Expected work costs
+0.1	Expected costs for patients/NHS
+0.1	Results variance and sensitivity analysis
+0.1	Adoption typology (purchase, leasing ect.)
+0.5	Systematic results monitoring and feedbacks collection concerning acquired technologies

Unit
[–].

Time reference
Annual survey.

Initial data availability
Ministry's of Health data; hospital documentation; surveys.

CLINICAL WASTE

Pre-requirements (only for operative hospitals)

- **Risk assessment**: presence of a unit or person in charge for risk management and/or adverse events control and/or hospital acquired infections committee and/or drugs committee which should promote clinical risks reduction and prevention.

Definition
The criterion evaluates the care quality in terms of risk control, which has a strong impact on health outcomes.

Aim
To propose strategies and tools to reduce and prevent clinical risks and adverse events, which damage patients' health and cause additional expenses.

Description
The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7).

$$\text{Clinical Waste} = \frac{(\text{x} \cdot \text{HAI} + \text{y} \cdot \text{ADE})}{5}$$

where:
HAI Hospital Acquired Infections
ADE Adverse Drug Events

References
Capolongo 2012; Capolongo et al. 2013a, b; Cinotti and Di Bella 2007; De Vries et al. 2008; Fraser and Spiteri 2011; Garner et al. 1988; Harbarth et al. 2003; Honigman et al. 2001; Nicastri et al. 2003; Pittet et al. 2005; Plowman et al. 2001; V.V.A.A. 2003; Tarasenko and Virone 2011; Trucco and Cavallin 2006; Trucco et al. 2008.

CLINICAL WASTE—hospital acquired infections

Definition
This indicator evaluates the effectiveness of the planned prevention protocols related to Hospital-Acquired Infections (HAI), for in-design hospitals or with respect to existing hospitals the incidence of infections acquired during hospitalization, which were not clinically visible neither in incubation at the admission moment, but occur, generally, at least 48 h after admission, during stay or after discharge.

Aim
To improve the healthcare structure's effectiveness in terms of health, analyzing a frequent typology of adverse events, which cause additional costs and significant complications for the system and the patient, and should therefore be reduced as much as possible.

Description
With respect to existing hospitals, the indicator expresses HAI incidence (defined as the number of new HAIs occurrences over 10,000 days of patient care) in the considered hospital compared to 2009s European average value: 4.8 % (Fraser and Spiteri 2011).

SCORE	HOSPITAL ACQUIRED INFECTIONS (%)
0	HAI > 6
2.5	4 ≤ HAI ≤ 6
5	HAI < 4

Concerning in-design hospitals the indicator evaluates the adequacy and efficacy of the tools chosen to prevent HAI.

SCORE	HOSPITAL ACQUIRED INFECTIONS
+3	Application of innovative technologies, ISO 5 (ISO 2010) operating theatre automatic and continuous air detection system, to enhance hospitals' level of hygiene and sterility
+1	Spread of internal protocols for HAI prevention
+1	Control and motivation to apply the mentioned protocols amongst employees

Unit
[–].

Time reference
Annual survey.

Initial data availability
Ministry's of Health data; hospital documentation; surveys.

CLINICAL WASTE—adverse drug events

Definition
The indicator evaluates strategies for prevention of harms caused by drugs misuse, due to the drug itself (side effects, overdose) or to its assumption (dose reduction discontinuous therapy), which can derive from therapeutic mistakes.

Aim
To promote the adoption of adequate drugs administration systems, including deep controls at each phase of the process, in addition to monitoring of outcomes concerning Adverse Drug Events (ADE) reduction.

Description
The indicator evaluates effectiveness and efficiency of the planned or implemented drug administration process, considering its crucial phases. Scores for **operative hospitals** are given if this requirements are achieved:

SCORE	ADVERSE DRUG EVENTS
Max. +1.5	Creation of a digital integrated-between-drugstore and-department and linked-to-other-entries version of
+0.375	Doctor's drugs prescription, describing dosage, composition, posology and their link to previous clinical analyses

SCORE	ADVERSE DRUG EVENTS
+0.375	Attestation of prescription from doctor in charge of drugstore
+0.375	Attestation from pharmaceutical preparations technician
+0.375	Attestation of occurred administration
+1	Integration between data reading from drugs boxes bar codes and patient's card and hospital information system
+1	Automatic alert system concerning: drugs interactions dose limits patient-specific contraindications
+1	ADE monitoring through analysis of clinical documents
+0.5	ADE monitoring employing software for electronic health record querying

Instead, scores for **in-design hospitals** are given if this requirements are achieved:

SCORE	ADVERSE DRUG EVENTS
+2.5	Presence of a digital, integrated-between-drugstore-and-department and linked-to-other-entries version of doctor's drugs prescription, describing dosage, composition and posology, attestation of prescription from doctor in charge of drugstore, attestation from pharmaceutical preparations technician and attestation of occurred administration
+1.5	Integration between data scanned from drugs boxes bar codes and patient's card in the hospital information system
+1	Automatic alert systems for drugs interactions, dose limits, patient-specific contraindications

Unit
[–].

Time reference
Annual survey.

Initial data availability
Ministry's of Health data; hospital documentation; surveys.

TECHNOLOGICAL WASTE

Pre-requirements

- **Health Technology Assessment**: presence of (or consultancy from) an HTA and/or clinical engineering unit and/or of a technical office able to deal with technical requirements of biomedical technologies and to consider correlated economic and clinical aspects.
- **Information systems**: presence of an information systems area owning the IT skills necessary to allow digital data's delivery and sharing and to promote the development of innovative strategies for communication and information management.

- **Resources management**: presence of a financial resources management area which analyses procurement and renovation issues and properly allocates funds.

Definition
The criterion evaluates the innovativity and appropriateness of the biomedical technologies in an existing hospital or the related evaluation during the design phase, including not only the traditional diagnostic and therapeutic ones, but also advanced information technologies, which can support healthcare services.

Aim
To promote the realization of an up-to-date technological equipment, which is useful and effective for patients and staff, avoiding waste or deficiency, optimizing work flows and improving the service quality.

Description
The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7).

$$\text{Technological Waste} = \frac{(x \cdot \text{ICT} + y \cdot \text{BTO})}{5}$$

where
ICT Information and Communication Technology
BTO Biomedical Technologies Obsolescence

References
Bakker 2002; Civan et al. 2006; COCIR 2009; Corso and Locatelli 2009; Demiris et al. 2008; Eysenbach 2001; Halamka et al. 2008.

TECHNOLOGICAL WASTE—biomedical technologies obsolescence

Definition
The indicator evaluates the age profile of the available biomedical technologies in an existing hospital or the level of innovation of the ones to be acquired by a newly designed hospital, in addition to the appropriate management of the devices, during their whole life cycle.

Aim
To promote the implementation of proper investments plans for acquisition, maintenance, refurbishment and replacement of biomedical technologies, which should be always safe and sustainably managed.

Description

For existing hospitals, the indicator evaluates the status of diagnostic medical imaging devices in the hospital according to *COCIR Golden Rules* (COCIR 2009) and to proper management criteria.

SCORE	BIOMEDICAL TECHNOLOGIES OBSOLESCENCE
+1	At least 60 % of the equipment is younger than 5 years
+1	Not more than 30 % is between 6–10 years old
+1	Not more than 10 % is older than 10 years
+0.5	Devices are up-dated/refurbished when suitable
+0.5	Replacement before end-of-life is connected to a scientifically proved improvement of cost/effectiveness ratio
+0.5	Devices replacement is correlated to their rate of use
+0.5	When dismissed devices are recycled/reused in different contexts or developing countries

Concerning in-design hospitals, the indicator evaluates the planned acquisition of diagnostic medical imaging devices.

SCORE	BIOMEDICAL TECHNOLOGIES OBSOLESCENCE
+2	At least 40 % of the acquired technologies are old-fashioned
+1	Replacement strategies are implemented
+1	An investment plan is available
+1	A digital queryable technology inventory is implemented

Unit

[–].

Time reference

Annual survey.

Initial data availability

Hospital documentation; technology inventory; surveys.

TECHNOLOGICAL WASTE—information and communication technologies

Definition

This indicator evaluates ICT introduction in the structure, to support care and data management processes.

Aim

To promote the spread of e-health strategies and tools, as means not only of innovation, but also of efficiency increase, costs rationalization and service quality improvement.

Description

The indicator expresses the level of ICT penetration in the considered healthcare structure, scoring the presence or the foreseen implementation of the most significant e-health tools as follows:

SCORE	ICT
+1	Electronic health record (EHR) in some hospital's departments
+1.5	EHR is used in every department
+2.5	Online access to clinical tests' results

Unit

[–].

Time reference

Annual survey.

Initial data availability

Hospital documentation; technology inventory; surveys.

Social Sustainability[2]

Among the three sustainability macro-areas, the *social* one has been the most neglected and underexplored (Partridge 2005); particularly in healthcare structures, where aspects as collaboration and involvement are so important. Notwithstanding the difficulties in defining it thoroughly, there are shared theoretical pillars to be considered. These last ones give the possibility to define *Social Sustainability* in healthcare structures referring to issues as *equity*, *diversity*, *interconnectedness*, *quality of life*, *inclusion*, *access*, *participatory processes*, *future perspective* and *governance* (Partridge 2005). Looking at other emerging issues, like sense of place, culture of health, safety, social cohesion, solidarity, and according to WACOSS definition of Social Sustainability (Colantonio 2009), Social Sustainability is in this context considered as the process of creating an accessible, integrated and equitable community that successfully meets users' needs of health and well-being. This aim is pursued through adequate facilities and people collaboration, in order to create a safe place, a community that, stimulating emotional-physical inclusion, becomes a landmark in its territory, spreading these behaviors among people and institutions, to guarantee them in the future.

According to this definition, it was chosen the minimum number of criteria able to assess most of the issues that characterize social sustainability in hospitals. A common

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thread is represented by a *user-centered vision.* Criteria and indicators were identified looking at people who live hospitals spaces: *staff*, *patients* and *visitors*, for example, taking into account their opinion through the *humanization* criterion, that evaluates the hospital's environment and policies. In an operative hospital this is a very important aspect because it allows to understand the actual hospital performances and its effectiveness, so as perceived by its users (Buffoli 2014a). To evaluate this criterion some pre-requirements must be satisfied; they were chosen looking at those aspects more perceivable by users. The *Comfort* criterion takes into account the hospital environment through quantitative data able to indicate micro-climatic conditions. In fact, in such type of spaces interior ambience quality is a very delicate and tricky issue, because of the multiplicity of factors that affect the hospital particularly during its operating phase. People's psycho-physical status and work environment positivity are also determined by the hospital structure, so the evaluation system evaluates its *distribution* (spaces organization, paths, etc.) in order to take into account its impact on people's well-being.

HUMANIZATION

Pre-requirements

- **Hospital accessibility**: the possibility for all the users, in particular for disabled people, to reach the hospital and to use its spaces and facilities in secure and autonomy conditions.
- **Adequate hygienic conditions**: constant and at least daily cleaning of the most critical areas (hospitalization rooms, operating theatre, etc.) and no contact between clean equipment and dirty one.
- **Adequate safety conditions**: sufficiently good security conditions with respect to regulations. Accessibility, visibility and integrity (according to the hospital typology take in consideration) of all the facilities required to reach the nearest *safe place* (Minister of Interior 1998), of all the safety equipment (signals, fire-extinguishers, emergency doors, etc.) and of the most frequented places (waiting rooms, escape routes, etc.).

Definition
The criterion evaluates the hospital's level of humanization both in its structures and in its services for all its users: patients, staff and visitors.

Aim
To encourage the centrality of the person.

Description
It evaluates users' experience inside the hospital's structure, from a psycho-physical point of view. The importance of a comfortable, collaborative and professional environment has been recognized to bring psycho-physical advantages to all the actors involved in the hospital reality: *patients*, whose psychological well-being helps their therapeutic process; *staff*, whose

motivation and productivity are influenced by a better working environment; *visitors*, who are positively impressed by a clean and functional hospital.
The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7).

$$\text{Humanization} = \frac{(x \cdot \text{SS} + y \cdot \text{SA} + z \cdot \text{Wb} + w \cdot \text{HP})}{5}$$

where:
SS Safety and Security
SA Social Aspects
Wb Well-being
HP Health Promotion

In the case of operative hospitals (OH) pre-requirements are analyzed looking to the real conditions of the hospital environments and to the real users' perception. Each indicator's score is calculated by a questionnaire which evaluates the different aspects considered; one for the hospital's staff, one for patients/visitors, one for the technical evaluator (for those aspects that require an objective evaluation). Available answers regarding perception (hospital staff and patients/visitors) of the hospital environment are: '*very satisfied*', '*fairly satisfied*', '*not really satisfied*' or '*not satisfied at all*'.
The results for each answer are calculated with the following formula:

$$x/y * 100$$

x total number of respondent which gave a certain answer
y total number of respondents giving valid answer to the question

The score assigned to the different aspects is the following:
- *zero*: <33 % people gave a positive answer;
- *medium score* (*max*/2): 33 % < percentage of people < 66 % gave a positive answer;
- *maximum score*: >66 % people gave a positive answer.

In a positive way are considered the answers '*very satisfied*' and '*fairly satisfied*'. (This specification on how positive is the level of safety perceived by the users gives more credibility to the questionnaire as opposed to a simple 'yes' or 'no').
In the case of in-design hospitals (IDH) pre-requirements are analyzed looking to the correspondence of the hospital environments to the minimum standards considered from regulations.
Each indicator's score is the result of a technical evaluation of hospital's project policies and strategies.

Note: in operative hospital evaluation, when the hospital's staff questions on a certain topic are different from patients/visitors' ones, the final score of the particular aspect of the indicator is obtained by an arithmetical average between the staff's responses and the patients'/visitors' responses. When these particular aspects are also evaluated by the technical evaluator, the final score is then given by the average between the technician's score and the previously calculated users' scores.

References

Alfonsi et al. 2014; Ambiente Italia Istituto di Ricerche 2013; Capolongo et al. 2014; Lindström and Eriksson 2005; Minister of Interior 1998; Office of the Deputy Prime Minister 2005; Spinelli et al. 1994.

HUMANIZATION—safety and security

Definition

The indicator evaluates the level of safety and security of users.

Aim

To encourage adequate safety and security policies. The indicator considers both the existing regulations and the hospital's policies about these aspects, especially users' final perception about them.

Description

Safety is fundamental for the psycho-physical well-being of hospital's users: patients, in a vulnerable condition, and staff, that have to focus only about their work, without other worries.
The total score is given by the sum of the following points (OH = Operative Hospitals; IDH = In-Design Hospitals):

SCORE	SAFETY and SECURITY ASPECTS	
	OH	IDH
+1.5	Perceived security with regards to theft	Policies about theft
+1.5	Trust in hospital services	Policies about patient's trust in hospital services
	Services like: hygiene, surgical operations, chances of contracting infections, etc.	
+1	Perceived personal safety	Policies about personal safety
+1	Presence of security control	Policies about the presence of security control

In the questionnaire for OH the possible answers regarding users' perception of the hospital are: '*very safe*', '*fairly safe*', '*not really safe*' or '*not safe at all*' (similar answers to evaluate perceived security). In a positive way are considered the answers '*very safe*' and '*fairly safe*' (or '*secure*').

Unit

[–].

Time reference

Annual survey.

Initial data availability

Direct questionnaires; valuation of hospital's programs and strategies.

HUMANIZATION—social aspects

Definition
The indicator evaluates the social cohesion inside the hospital.

Aim
To encourage participation and collaboration among all hospital's users (also in the design phase) and to increase the level of attention paid to the hospitals' social policies.

Description
It evaluates the hospital's attention toward social aspects, staff's collaboration and the level of user involvement (according to the hospital typology take in consideration), not only with the medical/therapeutic issues but also with the architectural/environmental ones.
The total score is given by the sum of the following points (OH = Operative Hospitals; IDH = In-Design Hospitals):

SCORE	SOCIAL ASPECTS OH	SCORE	SOCIAL ASPECTS IDH
+1.2	Presence and quality of a mediation, translating and interpreting service	+0.8	Presence of a mediation, translating and interpreting service
+0.9	Level of patient involvement in the therapeutic and design process (for the latter is evaluated also the staff involvement)	+1.5	Level of patient involvement in the therapeutic and design process
+0.7	Structure friendliness towards different cultures (presence of directions in different languages, of spaces that allow people with different cultures to accomplish their own customs, e.g. worship traditions)	+1.5	Structure friendliness towards different cultures (presence of directions in different languages, of spaces that allow people with different cultures to accomplish their own customs, e.g. worship traditions)
+0.6	Presence and use of spaces capable of accommodating meetings between staff and patients	+0.4	Presence of spaces capable of accommodating meetings between staff and patients
+0.4	Presence of spaces to give hospitality to patients' relatives	+0.8	Presence of spaces to give hospitality to patients' relatives
+0.9	Level of collaboration within hospital staff		
+0.3	Discriminatory behavior: all patients and staff are treated with the same care and professionalism regardless of their race, religion, sexual orientation physical and mental handicap, professional specialization		

In the operative hospital, a technician will analyze the presence of aspects 1, 2, 4, 5, 6.
Concerning points 1, 2 (therapeutic process), 5 and 6, the positive answer will yield the maximum score, the negative answer assigns 0 score.

For answers 2 (design process) and 4, scores assigned by the technician are the following:

- *zero*: answer is 'none';
- *33 % of total score*: answer is 'several';
- *maximum score*: 'most' or 'yes, all' is the answer.

Unit
[–].

Time reference
Annual survey once during the design phase and every time a major modification (structures/policies) is made.

Initial data availability
Direct questionnaires, direct observation of hospital's programs and environment, interviews for the operative ones; observation of the hospital's programs and project, as well as the design process.

HUMANIZATION—well-being

Definition
The indicator evaluates the level of overall well-being with regard to the hospital's environment and facilities.

Aim
To improve the level of attention paid to the well-being within the hospital, considered as a workplace and a service provider. Aspects as materials, colours and light have a positive effect on the psycho-physical well-being, improving staff performance and helping patient recovery.

Description
Hospital's structures and policies are evaluated looking to different aspects affecting psycho-physical well-being: colours, material, lighting, leisure activities, green areas, etc.
The total score is given by the sum of the following points (OH = Operative Hospitals; IDH = In-Design Hospitals):

SCORE OH	SCORE IDH	WELL-BEING ASPECTS
+2	+2	Comfort: colours, materials, artificial and natural lighting, furniture quality
+1.2	+0.9	Good and clear signals and paths within the hospital
+1	+1.5	Presence of activities/facilities for staff and patients/visitors: sport, leisure, culture, bar/restaurant areas, libraries, WI-FI areas, art, exhibitions, etc.
+0.8	+0.6	Quality/presence of green areas and outside views

Unit
[–].

Time reference
Annual survey; once during the design phase and every time a major modification (structures/policies) is made.

Initial data availability
Direct questionnaires; valuation of the project at the different phases of the design (e.g. color, light, material studies, simulation, etc.).

HUMANIZATION—health promotion

Definition
The indicator evaluates the level of health promotion and sustainable lifestyle pursued in the hospital.

Aim
To encourage the attention paid to the promotion of *salutogenic* (Lindström and Eriksson 2005) lifestyle and disease prevention in hospital policies.

Description
It evaluates the level at which the hospital can be an health promoter.
The total score is given by the sum of the following points (OH = Operative Hospitals; IDH = In-Design Hospitals):

SCORE	HEALTH PROMOTION	
	OH	IDH
+2.5	Presence of prevention and promotion campaigns	
+2.5	Presence and use of natural and ecological products and materials, non-toxic, recyclable, with a short supply chain	Presence and variety of natural and ecological products and materials, non-toxic, recyclable, with a short supply chain

The score (based on the technical evaluator questionnaire) is assigned to the different aspects by the following approach:

- *no score*: absence of promotion and prevention campaigns/no use of natural and ecological products and materials;
- *medium score value (max/2)*: presence of promotion or prevention campaigns/presence of natural or ecological products and materials;
- *maximum score value*: presence of both promotion and prevention campaigns/variety of natural and ecological products and materials.

Unit
[–].

Time reference
Annual survey.

Initial data availability
Direct valuation of hospital's strategies and projects; interviews.

COMFORT

Definition
The criterion defines comfort conditions for the indoor environment of a hospital analyzing the quality of air, thermal neutrality, acoustics, natural and artificial lighting.

Aim
To determine sufficient conditions for indoor air quality, visual, acoustical and thermal comfort, and to achieve satisfaction for the occupants of the healthcare facility in order to promote health through comfort in the indoor built environment.

Description
A satisfying quality of the indoor environment (emphasizing the importance of the relationship man-environment-object), must be guaranteed by the hygrothermal comfort, the availability and quality of natural light and view of the outside. All the analyzed aspects can enhance the quality of the indoor environment and can optimize the conditions of space for hospital users. The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7).

$$\text{Comfort} = \frac{(x \cdot \text{Dl} + y \cdot \text{TC} + z \cdot \text{IAQ} + w \cdot \text{Ac})}{5}$$

where
Dl Daylighting
TC Thermal Comfort
IAQ Indoor Air Quality
Ac Acoustic

References
BRE Global Ltd 2010; Buffoli et al. 2007; Capolongo 2001, 2006; CTI 1995, 2008a; ITACA 2011; USGBC 2011a, b; Mardajevic and Nabil 2005; Origgi et al. 2011; Premier of Council Ministers 1997; Spinelli et al. 1994.

COMFORT—daylighting

Definition
Day lighting for human beings, seems to be comfortable (visual, thermal), productivity-enhancing (activity of the medical staff, patients), healthy stimulating (visual and circadian system), psychologically influential (contact with the outside environment is desired).

Aim
To evaluate and improve the of quality level for lighting.

Description
High quality of lighting has its main finality in the physical and psychological wellbeing of medical staff, patients and visitors. Nonetheless it is strongly related to architectural composition, energy costs and consumption by lighting systems. A right approach is inclusive of strategies such as: performance and visual comfort; flexibility in the organization of spaces; maintenance of the luminous flux during the entire day; esthetical value of the environment (intensity and colour of the light); differentiation of the illuminance in relation to the zone or activity (different lighting scenes); stimulation and productivity (circadian rhythms); stress reduction (natural light view of the outside, allows the perception of time passing by, contact with outside events).
The variable which compose the indicator are:

1. Daylight Factor, $DF_m \geq 2$ % for regularly occupied spaces; it can be also calculated with the following formula:

$$FLD_m = \frac{A_f \cdot \tau_l}{(1 - \rho_{lm}) \cdot A_{tot}} \cdot \varepsilon \cdot \gamma [\%]$$

where:

A_w	area of the transparent surface of the window [m^2];
τ	correction factor of the glass [–];
ε	windows factor [–];
γ	retraction coefficient of the plane of the window to the façade;
ρ_{lm}	median coefficient of light reflection of the inner surfaces;
S	area of the internal surfaces that delimit the space [m^2].

2. uniformity ratio, $U = E_{min}/E_{avg} \geq 0.2$ for over 50 % of the floor area, in which E is the illuminance (*E = 1 indicates complete uniformity*);
3. provide a connection to the outdoors through the introduction of daylight for 90 % of regularly occupied spaces;
4. integration of natural and artificial light with control systems in function of the daytime and meteorological conditions (shading for natural daylight and dimmeration for artificial lighting);

5. daylight design with dynamic methods, like Climate-Based Daylight Modeling (CBDM) using parameters *Daylight Autonomy* (DA), *maximum Daylight Autonomy* (D_{Amax}), *continuous Daylight Autonomy* (DA_{con}), Useful Daylight Illuminance (UDI);
6. calculation of UDI achieved ≥ 60 % and calculation of fell-short and exceeded for system integration and to avoid glare;
7. presence of external sun shadings or window integrated blinds, at least 90 % of south façade.

The total score is given by the following:

SCORE	DAYLIGHTING
1	First requirement is achieved
2	First requirement is achieved and one between 2, 3 or 4
3	First requirement is achieved and two between 2, 3 or 4
4	First requirement is achieved two between 2, 3 or 4 and one between 5, 6 or 7
5	First and fourth requirements are achieved and three among the others

Unit
[–].

Time reference
Annual survey.

Initial data availability
Sections, plans, elevations with indications of lighting equipment and use destination of the spaces.

COMFORT—thermal comfort

Definition
The indicator evaluates the individual satisfaction concerning thermo-hygrometric conditions of the environment (subjective definition) and thermal neutrality defined as the state in which the thermal accumulation is none and the organism leaves inactive mechanisms of thermal regulation (objective definition).

Aim
The purpose is to improve thermal comfort in hospital conditions for patients medical staff and visitors. This creates better conditions for general psychological states to work and other activities in the hospital.

Description

Thermal comfort in healthcare facilities is an important objective to be achieved for patients who need the best conditions to get cured for medical staff who spend long hours inside the building and need high comfort for their work and also for visitors. Thermal comfort is function of six parameters:

- 2 individual parameters (related to the user): Energetic metabolism (M) and Thermal resistance of clothing (I_{cl});
- 4 environmental parameters (related to the microclimate): air temperature medium radiant temperature air velocity relative humidity.

Zones such as operating rooms labs and all the zones that require a high air change per hour (higher than 6) are excluded from the application of the indicators. This indicator is suitable for all the zones (e.g. beds consulting rooms offices and so on) which are subject to both temperature and humidity control obtained with the combination of primary-air and hydronic terminals.

The total score is given by the following (OH = Operative Hospitals; IDH = In-Design Hospitals):

SCORE	THERMAL COMFORT
1	$-1 \leq$ Predicted mean vote (PMV) ≤ 1
2	$-0.5 \leq$ PMV ≤ 0.5
+1	Vertical temperature difference under 3 °/m because of predicted percentage of dissatisfied (PPD) < 5 % in hospital blocks
+1	Air velocity: $V_a = 0$–1 m/s
+1	Relative humidity: $\Phi = 30$–70 % for OH
	Relative humidity: $\Phi = 40$–60 % for IDH

Unit

Φ = [Pa]; T = [°C] or [K]; v = [m/s]; M = [met]; I_{cl} = [W/m^2].

Time reference

Annual winter design day, annual summer design day. In the case of in-design hospitals every modification implies the evaluation upgrading.

Initial data availability

Architectural design of the facility and occupancy profile of every environment zone defined within the facility.

COMFORT—indoor air quality

Definition
The indicator evaluates the indoor air quality, in both aspects of security and comfort.

Aim
To improve air quality to reduce infection risks with good air quality and proper ventilation air flow within the hospital.

Description
Indoor air quality in a close environment is considered acceptable when there are not present specific pollutants in harmful concentrations and when at least 80 % of occupants express satisfaction at this regard.
Healthcare facilities require very high air quality for all their occupants patients with health problems medical staff working long hours and visitors under emotional strain. These facilities have corridors and spaces with high flows of people every day emphasis should be put on minimizing the transmission of infections within the environment and good air quality helps people feel well psychologically and physically in these facilities where timing is important for the medical staff moving fast to serve people sometimes crowded and long queues of waiting visitors or patients. There are many variables that influence the quality of the air. The construction materials are subject of emissions people ventilation systems cleaning chemicals, etc. Therefore obtaining good IAQ has three ways of doing so: reduction of sources of air pollution, removal of pollutants at the source and dilution of pollutants by ventilation with external fresh air.
Scores for **operative hospitals** are given if this requirements are achieved:

SCORE	INDOOR AIR QUALITY
+1	Estimation of people flow per every corridor or space which is not regularly occupied and of the hours of occupation to calculate the right air flow for ventilation in all time span to assure good air quality efficiency of ventilation and energy savings for ventilation
+2	Design of ventilation systems (natural and mechanical) with schemes explaining the concept solutions for each case with air in-/outflow indication defining how pollutants are diluted and the right positioning of the air ventilation system so to take into account the position of occupants in the environment
+1	Integration of natural ventilation with mechanical ventilation where possible and integration of passive natural ventilation strategies e.g. stack effect single side ventilation or cross ventilation solutions atrium ventilation solar chimneys wind and stack assisted ventilation fan assisted
+1	Innovative solutions for reduction of pollutants and removal of pollutants (low emission construction), materials cleaning chemicals free of volatile organic compounds (VOC) innovation in ventilation system

Scores for **in-design hospitals** are given if this requirements are achieved:

SCORE	INDOOR AIR QUALITY
1	Calculations according to norm UNI EN 15251 (CTI 2008a) or the Italian reception the UNI 10339 (CTI 1995), has been made and mechanical ventilation systems satisfy the requirements for each environment
2	A correct estimation of persons' flow in space which is not regularly occupied
3	Design of both natural and mechanical ventilation systems, with schemes explaining the concepts solution for each case with air flow in/out indication, how pollutants are diluted and the right positioning of the air ventilation system placed so to take in account the position of occupants in the environment
+2	Innovative solutions for reduction of pollutants and removal of pollutants (low emission construction materials, cleaning chemicals free of VOC)

Unit
[–].

Time reference
Annual survey. In the case of in-design hospital every modification implies an evaluation upgrading.

Initial data availability
Architectural design of the facility and occupancy profile of every area defined within the facility.

COMFORT—acoustic

Definition
The indicator is concerned with the study of sound propagation in the neighboring rooms.

Aim
To provide building occupants with an environment free of intrusive or disturbing noise levels and to separate the interiors that require more privacy from noise sources through a strategic location.

Description
The excessive noise in the spaces caused by continuous reflection of sound waves is an important issue in large areas of the hospital that are often coated with hard and smooth materials, easy to wash, but with a weak sound absorption. The acoustic comfort can be guaranteed with the use of sound insulation or sound-absorbing materials. The indexes (Premier of Council of Ministers 1997) to be monitored are:

- Transmission Loss (TL), R'_w: 55 dB
- Weighted standardized level differences, D_{2mnTw}: 45 dB
- Weighted standardised impact sound pressure, L'_{nw}: 58 dB
- Maximum indoor ambient noise level, L_{Amax}: 35 dB
- Indoor ambient noise level, L_{Aeq}: 25 dB

The total score is given by the sum of the following indications (OH = Operative Hospitals; IDH = In-Design Hospitals):

SCORE	ACOUSTIC
1	Solutions to minimize the noise determined by heating ventilation, air conditioning elevators, plumbing systems are improved
2	Public areas that could generate interference sources, are separated from inpatient rooms to ensure quiet
+1	The value of R'_w is less than 55 dB (OH) or 53 dB (IDH)
+1	The value of D_{2mnTw} is less than 45 dB (OH) or 43 dB (IDH)
+1	The value of L'_{nw} is more than 58 dB (OH) or 60 dB (IDH)

Unit
[dB].

Time reference
Annual survey.

Initial data availability
Direct measurements on-site technical plans of the building.

DISTRIBUTION

Definition
The criterion evaluates the efficiency of paths and access distribution of the spaces.

Aim
To allow users clear movements, in less time and in the best security condition and to optimize resources and staff while working.

Description
It takes into account every characteristic that is related to functional layout and linking among spaces and functions. It esteems a deep study of mobility inside hospital that helps the good organization of paths and spaces for every kind of user.

The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7).

$$\text{Distribution} = \frac{(x \cdot AP + y \cdot HB + z \cdot SF + w \cdot Dep)}{5}$$

where:

AP Accesses and Paths
HB Hospitalization Blocks
SF Spaces Flexibility
Dep Departments—doctors' offices

References

Buffoli et al. 2012a, b; Capolongo et al. 2012, 2013a, b; USGBC 2011a, b; Velsen 2012; Zevi 2003.

DISTRIBUTION—accesses and paths

Definition

The indicator defines the effectiveness and efficiency of paths and accesses.

Aim

To shorten the distances of paths and to ensure the accessibility of spaces.

Description

The evaluation takes into consideration the following three aspects:

1. corridors' width that allows the passage of the stretcher;
2. separation of all hospital paths (corridor for medical staff and public one) with the exception of hospital blocks;
3. separation of the accesses (emergency room, inpatient/outpatient/ diagnostic services).

The total score is given by the following:

SCORE	DEPARTMENTS—DOCTORS' OFFICES
1	Corridors' width less than 2.25 m and some of the accesses and paths are different (<50 % of the surface)
2	Corridors' width more than 2.25 m and some of the accesses and paths are different (<50 % of the surface)
3	Corridors' width more than 2.25 m; accesses are separated and some paths too (<50 % of the surface)
4	Corridors' width more than 2.25 m; accesses are separated and the major of paths too (>50 % of the surface)
5	Corridors' width more than 2.25 m and all the accesses and paths are distinct

Unit
1 = [m]; 2–3 = [–].

Time reference
Calculated in the evaluation phase, remains valid until further modification to the distribution system.

Initial data availability
Construction project.

DISTRIBUTION—hospitalization blocks

Definition
The indicator defines the hospitalization blocks' functionality and flexibility, both from the operational and architectural-functional point of view. It verifies the distances among rooms and control areas, and vertical connections.

Aim
To increase the hospitalization spaces' efficiency and to provide users with small displacements and decrease the risk factor.

Description
The evaluation takes in consideration the following two aspects:

- Hospitalization block typology; the possible typologies are:
  A central corridor and rooms in one of the two sides;
  B central corridor and rooms at the two sides;
  C radial disposition of the rooms and central control zone;
  D quintuple organization of the rooms.
- Maximum distance between the patients rooms and main vertical connections, the distance is measured from the entrance of the room farthest to the vertical connections (block stairs and lifts).

The total score is given by the following:

SCORE	HOSPITALIZATION BLOCKS
1	A-typology with max distance equal or lower than 25 m (between rooms and vertical connections)
2	B-typology with max distance higher than 25 m
3	B-typology with max distance equal or lower than 25 m
4	C/D-typology with max distance higher than 25 m
5	C/D-typology with max distance equal or lower than 25 m

Unit
1 = [–]; 2 = [m].

Time reference
Calculated in the evaluation phase remains valid until further modification to the distribution system.

Initial data availability
Construction project.

DISTRIBUTION—space flexibility

Definition
The indicator evaluates the possibility of spaces to have their function changed with the lowest amount of physical and human resources.

Aim
To increase the hospital space's flexibility to ensure continuous and lasting efficiency and facilitate spaces adaptability over time.

Description
Following characteristics are evaluated:

1. Presence of technical corridors (ceiling or floating floors), for a minimum of 20 % of the total surface, which permit the passage and maintenance of technical systems (electrics, IT, Medical gases, fire systems, etc.);
2. Presence of 'soft spaces', defined as areas with low specific content which can be easily transferred, such as storage rooms or administrative offices (for a minimum of 5 % of the total hospital blocks' surface) located close to those which, according to plausible forecasts, may be spaces that will require future expansion;
3. Presence of future use rooms, (rooms inside the hospital construction, but not completed in the interior) for a surface of 5 % of the total surface, situated where they will be used without disturb or the need of moving other functions (to give the possibility to enter directly from the main paths);
4. The possibility of an horizontal expansion for a minimum of 30 % of the covered surface at the ground (construction footprint), excluding the surface of hospital blocks if they are present. This expansion has to be possible without destroying any existing part, except for the connection spaces that have to be set up in order to be functional. The possibility of a vertical expansion for a minimum of 75 % of the roof surface (not yet occupied by plants or systems in general; in this case plants can cover up to 40 % of the total roof surface). The horizontal or vertical expansion has to be verified not only looking at the real surface availability, but also at the presence of prearranged structures and systems;

5. Possibility to remove 50 % of internal partitions;
6. Presence of modular furniture, for a minimum of 50 % of the total (based on the cost of the total furniture), that can be easily rearranged.

The total score is given by the following:

SCORE	SPACE FLEXIBILITY
1	One strategy among 1-2-3-4 is implemented
2	Two strategies among 1-2-3-4 are implemented
3	Three strategies among 1-2-3-4 are implemented
4	The first four strategies are implemented together with one between the fifth and the sixth
+1	Presence of modular furniture

Unit
1-2-3-4 =[m^2]; 5 = [m]; 6 = [€].

Time reference
Calculated in the evaluation phase, remains valid until further modification to the distribution system.

Initial data availability
Hospital's documents, construction project.

DISTRIBUTION—departments

The indicator defines the departments' functionality and flexibility. It checks the presence and quality of relax areas.

Aim
To improve the research quality and to study spaces and to ensure ease in sharing information and experiences.

Description
The evaluation takes in consideration the following two aspects:

1. Departments' position; the possible typologies are:
   - A many isolated departments, generally linked to hospital blocks;
   - B singular space for departments, with a classical distribution, like offices;
   - C singular place for departments, with an innovative distribution, such as open space, etc.
2. Presence of relax areas.

The total score is given by the following:

SCORE	DEPARTMENTS
1	Typology A, with relax spaces
2	Typology B, without relax spaces
3	Typology B, with relax spaces
4	Typology C, without relax spaces
5	Typology C, with relax spaces

Unit
[–].

Time reference
Calculated in the evaluation phase, remains valid until further modification to the distribution system.

Initial data availability
Construction project.

Environmental Sustainability[3]

It made the philosophy and technical approach to design and operation of healthcare structures inadequate. Moreover the necessity to reduce the impact of human activity on the environment requires the optimization of resource consumption. Nonetheless when the hospital is yet operative, solutions that ensure the highest results at the lowest expenses must be favored.

According to the previous considerations it is easily noticeable how the main topic around the issue is the reduction of consumption, which is more relevant than the improvement of systems to increase efficiency in energy production.

The topics that mainly characterize the macro-area are *energy supply, waste production, water consumption* and *urban planning*.

The energy chain is wholly considered: energy produced by renewable resources is promoted with particular focus on Combined Heat and Power (CHP) plants; the reduction of consumption is focused not only on the efficiency of the system, but also, in the case of the operative hospitals, on awareness and education of hospital staff.

With regard to waste, the hospital's performance is evaluated in terms of quantitative production and are privileged the most favorable solutions of the so-called

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virtuous waste cycle management: minimization, reuse and recycling. Strong attention is given also to the water problematic, sometimes forgotten because of low tariffs and the apparent abundance of resources. The good integration of the hospital in the local community and environment is taken into account by the *urban planning* indicator, that also verifies complex accessibility and connection with transport.

SAVING with EFFICENCY

Pre-requirements

- **E-team**: constitution of an high skilled and multidisciplinary Energy team, to better analyze all the different aspects in which energy is involved.
- **Control and monitor**: the installation of individual lighting and thermal control system at the lowest micro scale, enables staff to reduce waste; moreover it can ensure high comfort, since the optimal hygrothermal and lighting conditions change from a place to another, also in accordance to their occupancy factor.
- **Technical requirement**: observation of a short things-to-do-and-not-do list is advisable:
  - nominal efficiency of heat generator at least of 90 % (referred to Lower Heating Value);
  - no heating must be done directly from power, even though it derives from renewable sources;
  - EER of chillers at least 3 (this value has to be referred to an outdoor air temperature of 30 °C for air cooled chillers or 20 °C for water cooled chillers);
  - decoupled production of fluids at high and low Temperature (both heating and cooling). If this prerequisite is not satisfied, the score for the indicator ‘terminals’ will be zero;
  - obtaining at least 3 points in Envelope Thermal Performance.

Definition
This criterion evaluates the outcomes of the undertaken actions in order to reduce hospital’s energy demand.

Aim
To evaluate the effort and the goals achieved by the Energy team in terms of reducing energy demand: Reducing Energy (RE) demand helps to increase the Renewable sources penetration in consumes definition (for the same RE produced).

Description
The criterion is focused on the technologies and actions that can reduce energy demand. The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7).

$$\text{Saving with efficiency} = \frac{(x \cdot \mathrm{EI} + y \cdot \mathrm{Li} + z \cdot \mathrm{HR} + w \cdot \mathrm{Te})}{5}$$

where
Li Lighting
HR Heat Recovery
Te Terminals

References
Brioschi et al. 2010; Buffoli et al. 2012a, b; Incropera et al. 2006; Italian Parliament 1991; Regione Lombardia 2009; Rizzo 2009.

SAVING with EFFICENCY—educinformation—only for operative hospitals

Definition
This indicator evaluates how much the staff is energy responsible and how end users are involved in the hospital's energy efficiency.

Aim
To reward hospitals with an E-team able to train and stimulate hospital's staff toward reducing energy requirement of wards.

Description
The object of evaluation is the level of information and education of the hospital's staff regarding the energy theme.
The total score is given by the sum of the following points:

SCORE	EDUCINFORMATION
+1	Opinions and suggestions are collected to promote energy efficiency and to point out malfunctioning
+1	Presence of an energy-person-in-charge for each ward
+1	Courses were held during the year, for the promotion of energy efficiency
+1	Information campaigns (different from courses) were conducted to promote energy efficiency
+1	Economic incentive to promote energy efficiency (e.g. reward the most sustainable ward)

Unit
[–].

Time reference
Annual survey.

Initial data availability
Interviews are used to evaluate the actions taken by the E-team or the humanization office to form and stimulate hospitals staff to reduce the energy requirement of their ward.

SAVING with EFFICIENCY—lighting

Definition
Correct lighting, both natural and artificial, plays a leading role in hospital daily life, on patient's comfort and on productivity. Promoting synergy between natural and artificial lighting helps in saving costs.

Aim
To minimize power demand through a correct design phase and thanks to the introduction of highly efficient artificial lighting devices.

Description
The indicator considers with the same weight both the efficiency of the artificial lighting system, in terms of power absorption and its integration with natural daylight.

$$\mathrm{Li} = 0.5\mathrm{A} + 0.5\mathrm{B}$$

where:

A accounts for the efficiency of the lighting system and it is defined as:

$$\mathrm{A} = \frac{\mathrm{kW\ lighting\ } \geq \mathrm{A\ class}}{\mathrm{kW\ total\ lighting}}$$

For this parameter the energy class of the lighting bulbs is determined according to the EU energy label.

B is the parameter that accounts for the interaction with natural daylight (referring to **Daylighting indicator** in 'Comfort' criterion) and it is equal to:

$$B = \frac{Daylighting\ indicator\ score}{5}$$

Scores are assigned according to the following:

SCORE	Li
1	0.15–0.3
2	0.3–0.45
3	0.45–0. 6
4	0.6–0.75
5	>0.75

Unit
A parameter is [kW/kW]; B is [lux].

Time reference
Annual survey.

Initial data availability
Total lighting power can be estimated through technical sheet of lighting design project and data from maintenance report.

SAVING with EFFICIENCY—heat recovery

Definition
The indicator evaluates the technological and design efforts done to recover as much wasted heat as possible.

Aim
To evaluate actions token on design and renovation phase to reduce energy consumption by recovering, where possible, waste heat to pre-heat or heat other work fluids.

Description
Object of the evaluation is the amount of waste energy that is recovered both from air and water/steam. The total amount of recoverable energy can be evaluated by conducting a deep analysis (e.g. pinch analysis), but coupling different fluids must be feasible not only from an energetic point of view but also from economic one. The indicator is defined as:

$$HR = 0.5A + 0.5B$$

where:

A is the parameter that accounts for the heat recovery from fluids (except air) and it is equal to one if any relevant solution is adopted zero otherwise;

B is the parameter that accounts for the energy recovered from air: it is the ratio between the amount of hospital volume on which a heat recovery process has been applied and the total hospital volume served by air-conditioning system. This parameter assumes zero value if the heat recovery devices are not coupled with a control system which ensures heat recovery only when it is convenient.

Scores are assigned according to the following:

SCORE	HR (%)
1	20–35
2	35–50
3	50–65
4	65–80
5	>80

Unit
B parameter in terms of [m^3/m^3].

Time reference
Annual survey.

Initial data availability
Data can be found in technical sheets, operational plant, control room.

SAVING with EFFICIENCY—terminals

Definition
The indicator evaluates the presence of heat exchangers that work with low temperature difference between hot and cold flux.

Aim
To spread diffusion and use of highly efficient terminals working with low different temperatures, ensuring fuel consumption savings.

Description
If there is need of producing heat both at high and low temperature, different equipment should be used for each level of temperature. This is valid for both heating and cooling: terminals are classified as 'low' temperature if they provide heat with transfer fluid temperature between 35 and 45 °C; they are classified as 'high' temperature if they provide cooling with transfer fluid temperature between 10 and 14 °C.

$$T = 0.5H + 0.5C$$

where:

H is the ratio between the floor area heated by low temperature terminals and the total floor area heated by hydronic systems;

C is the ratio between the floor area cooled by high temperature terminals and the total floor area cooled by hydronic systems

It can happen that low temperature (or high one for cooling) terminals, receive energy by a heat exchanger which is coupled to a higher (or lower for cooling) temperature plant loop. This is not energetically convenient. The advantage of using low (and high for cooling) temperature terminals is actually reached if those terminals are fed by devices such as heat pump, solar collector and other equipment which can actually determine an energy saving by working at that level of temperature.

SCORE	Te (%)
1	20–35
2	35–50
3	50–65
4	65–80
5	>80

Unit
[m^2/m^2].

Time reference
Annual survey.

Initial data availability
Data can be found in technical sheets, operational and design plan.

ENVELOPE TECHNOLOGIES

Definition
The criterion considers the technologies designed for the envelope of the building, in particular the envelope thermal performances, the passive and active solution for energy saving, the construction system and the maintenance installations.

Aim
The criterion aims to measure how innovative is a building for what concern modern solutions applicable to the envelope and to value the energy losses through the envelope and the easiness of maintenance.

Description
It focuses its attention on different elements that are relevant to evaluate the degree of innovation, as thermal features of the envelope to waste less energy and the design of an effective and integrated maintenance system. The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7):

$$\text{Envelope technologies} = \frac{(x \cdot \mathrm{ETP} + y \cdot \mathrm{MT} + z \cdot \mathrm{CT} + w \cdot \mathrm{PAT})}{5}$$

where
ETP Envelope Thermal Performances
MT Maintenance Technologies
CT Constructive Technology (only for in-design hospitals)
PAT Passive and Active Technologies (only for in-design hospitals)

References
Aste et al. 2011; CENED 2011; CTI 2012, 2008b; European Parliament and the council of the European Union 2002; Italian Parliament 1991; Jørgensen 2004; Minister of Economic Development 2010; Presidency of the Italian Republic 2011.

ENVELOPE TECHNOLOGIES—envelope thermal performances

Definition
The indicator evaluates the thermal performance of the building envelope.

Aim
To measure the global thermal performance of the envelope of the building in order to improve building performances.

Description

To evaluate this indicator the thermal transmittance of envelope components is necessary.

The evaluation of an operative hospitals analyzes the whole thermal performance or the improvement of the dispersing surfaces performances with respect to the original project, through the analysis of the thermal transmittance or its reduction, resulting in an improvement intervention carried out in the hospital. Score is given if the following requisites are achieved:

SCORE	ENVELOPE THERMAL PERFORMANCE
1	If there are selective or dual chamber glasses in windows
1	Presence of a ventilated and isolated roof or a green roof
+1	If the thermal transmittance has decreased more (or equal) than 30 % after the intervention and there is no presence of thermal bridges (they have been solved) or hospital structure realized after 1991 (Italian Parliament 1991)
+2	If the thermal transmittance has decreased more (or equal) than 50 % after the intervention and there is no presence of thermal bridges (they have been solved) or hospital structure realized after Directive 2002/91/CE (European Parliament 2002)
+3	If the thermal transmittance has decreased more (or equal) than 70 % after the intervention and there is no presence of thermal bridges (they have been solved) or thermal performance of the hospital respects the national current regulations

In the case of in-design hospitals, the average thermal transmittance of the principal elements and the avoidance of thermal bridge are the main parameters for the evaluation of the indicator. Considering:

$$U_{average} = \frac{U_1 A_1 + \cdots + U_n A_n}{A_1 + \cdots + A_n}$$

where:

U_1 is the thermal transmittance first component;

A_1 is the area of the first component;

U^* is the maximum thermal transmittance according to MD 26-01-2010 (Minister of Economic Development 2010)

Score is given if the following requisites are achieved:

SCORE	ENVELOPE THERMAL PERFORMANCE
+1	Opaque vertical structures ($U \leq U^*$)
+1	Opaque horizontal structures—roof ($U \leq U^*$)
+1	Opaque horizontal structures—floor ($U \leq U^*$)
+1	Windows ($U \leq U^*$)
+1	Thermal bridges (corrected)

Unit
[W/m^{2}K].

Time reference
Annual survey.

Initial data availability
In general, the stratigraphy of the historical and new intervention envelope. It is necessary knowledge about thickness [m], density [ρ], vapour resistance factor [μ], specific heat [c], thermal conductivity [λ] of each material which constitutes the stratigraphy.

ENVELOPE TECHNOLOGIES—maintenance technologies

Definition
The indicator evaluates the adoption of integrated technologies to realize an efficient, effective and economic maintenance.

Aim
To measure the maintenance technology according to their efficiency, rapidity to reach the scope and their good integration in the envelope.

Description
It focuses its attention on the technologies designed to guarantee a periodical and frequent maintenance of the building envelope. The hospital needs that the façade especially the transparent surfaces is cleaned frequently without an excessive investment.
Scores are assigned according to the following:

SCORE	MAINTENANCE TECHNOLOGIES
1	Life-lines rope access systems
2	Aluminum monorails without platforms, walking, roof car, stairs
3	Aluminum monorails with permanent platforms
+1	Cleaning semi-automated system/easy cleaning properties
+1	Integration of these system in the façade

Unit
[–].

Time reference
Annual survey.

Initial data availability
Project plans building maintenance plans.

ENVELOPE TECHNOLOGIES—constructive technology—only for in-design hospitals

Definition
The indicator looks at the adoption of integrated traditional or innovative construction technologies for providing a system that is fast and cheap.

Aim
The indicator aims to measure the prefabrication degree of the building. Many solutions, if planned in time can save time and money, providing the same performance.

Description
The indicator focuses its attention on the construction system of the hospital. There are traditional techniques, like the ones based on the concrete that requires the presence on the building site of many workers for a long time. There are others instead prefabricated that reduce construction time and can reach better performances. On the other hand they need specialized workers, the products are more expensive and mistakes cannot be corrected on the site. The total result is given by the sum of the following points:

SCORE	CONSTRUCTIVE TECHNOLOGY
+2	Traditional or prefabricated structure: qualitative estimation of the degree of prefabrication of the structural elements
+2	Traditional or prefabricated slabs, roof, internal and external walls: qualitative estimation of the degree of prefabrication of the partitions
+1	Traditional or prefabricate components (bathrooms, etc.): qualitative estimation of the degree of prefabrication of the components

Unit
[–].

Time reference
Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
Project plans constructor, brochures and documents.

ENVELOPE TECHNOLOGIES—passive and active technologies—only for in-design hospitals

Definition
The indicator looks at the adoption of passive and active technology in the building envelope.

Aim
The indicator aims to measure how is innovative a building for what concern modern solution applicable to the envelope.

Description
The indicator focuses its attention on the technologies to avoid waste of energy or to produce, actively, energy. There are many passive technologies like shadings or different façade solutions or special performing glasses or greenhouses or green roofs, etc. There are also active sources for renewable energy, like photovoltaic panels that can be more or less integrated in the envelope. The total result is given by the sum of the following points:

SCORE	PASSIVE and ACTIVE TECHNOLOGIES
+2	The presence of both external or integrated shadings like shutters, venetian blinds or roller blinds with a value g ≤ 0.4, according to UNI EN 13363-1 (CTI 2008b), and selective glasses, low-emissive glasses, etc. with shadings' surface >70 %
+1	The presence of photovoltaic, cells integrated, inorganic or organic ones that cover a surface >30 % of the overall façade surface or >70 % of the overall roof surface
+2	Presence of ventilated façades, double skin façades and natural ventilation systems; or Green houses with a surface >2 % of the net surface; or a surface >30 % of the roof surface for green roofs; or a surface >0.5 % for light openings and solar tubes

Unit
[m^2].

Time reference
Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
Project plans, constructor brochures and simulation programs.

WATERCARE

Pre-requirements

- **Control and monitor**: to be able to monitor the water consumption water meters have to be installed on water supply of each building. If buildings have major water consumers that correspond to water demand of 10 % of overall building demand (such as swimming pool), separate water sub-meters should be installed before this consumers. If Building Management Systems exist, all sub-meters should be connected to it, to be able to monitor the consumption real time and to intervene if necessary.

Definition
The criterion is used to promote a lower consumption of potable water and to reward the implementation of the solution undertaken to save water.

Aim
To reduce potable water consumption without affecting real needs of the hospital.

Description
The criterion brings into consideration various strategies which are aimed to asses and reduce potable water consumption. The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7):

$$\text{Water care} = \frac{(x \cdot WC + y \cdot BE + z \cdot LW + w \cdot WR)}{5}$$

where:
WC Water Consumption (only for operative hospitals)
BE Building Equipment (only for in-designing hospitals)
LW Low Water Use Fittings
WR Water Recycling

References
BRE Global Ltd 2010; ITACA 2011; USGBC 2011a.

WATERCARE—water consumption—only for operative hospitals

Definition
The indicator gives information about potable water consumption in hospitals.

Aim
To give precise information about consumption of potable water in the hospital.

Description
The indicator is calculated from data about yearly consumption and normalized by square meters of the building. Those values consider also the water consumption for laundry services.

Scores are assigned based on the following:

SCORE	WC
1	1500–1250
2	1250–1000
3	1000–750
4	750–500
5	<500

Note: if laundry services are assigned to an external company which provides by itself for water needed for laundry operations range values must be reduced 15 %.

Unit
[(liters/m^2)year].

Time reference
Annual survey.

Initial data availability
Based on potable water flow monitoring and square meters of the hospital.

WATERCARE—building equipment—only for in-design hospitals

Definition
The indicator intends ensure the installation of efficient equipment, to reduce the consumption of potable water in non-potable processes.

Aim
The main purpose of the indicator is to reduce the use of potable water in the non-potable processes.

Description
For each of the following requirements complied one credit has been assigned. Maximal number of credits is 5 and overall score will be the sum of sole requirements complied:

SCORE	BUILDING EQUIPMENT
0	No specific strategies has been anticipated
+1	Large frame X-ray processor and/or 150 mm in length should use film processor water recycling unit, smaller one are excluded from the rule
+2	Water used in heating/cooling processes is technical, non potable water and the process is closed-loop

SCORE	BUILDING EQUIPMENT
+1	When a food waste disposer is used, use cold water, equip systems with load sensing device that regulates the water use to 3.8 L/min in a no-load situation and 11–42 L/min in full load situation and automatic time shutoff that shall have a 10-min time-out with a push button to reactivate
+1	If irrigation is going to be performed using recycled/rainwater (system drop by drop) or the plants are local and dependant only on precipitation (so no need for irrigation)

Unit
[–].

Time reference
Calculated in the design phase remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
In the design stage data should be derived from technical documentation accompanied by manufacturer's equipment specification.

WATERCARE—water recycling

Definition
The indicator represents amount of rainwater and groundwater collected during the year or grey water reused, to cut the use of potable one.

Aim
To reward actions token in order to reduce use of potable water by recovering rainwater, reusing grey water and using groundwater.

Description
Hospital planners has the possibility to choose the strategy to satisfy requirements according to the specific context in which the hospital operates: any ratio between usage of grey and rain water can be freely decided to supply water flushing demand and irrigation. Total predicted flushing demand can be estimated on the basis of following variables:

- number of daily building users;
- effective flush for WCs and urinals;
- estimated number of WC/urinals uses per occupant per day multiplied by the defined period of collection.

Typical values are: 1.3 WC uses per person per day, 2 urinal uses per person per day (assuming that 50 % of occupants will use urinals during a day). Tank size should be estimated according to projected demand: water for

toilet, green areas irrigation, cleaning and different processes. If these requests are met, a certain number of credits will be assigned.
The following formula can be used to calculate the volume of collectable rainwater:

$$\sum (A_{RF} * C * R_{coef} * F_{coef} * D_{col})$$

A_{RF} annual rainfall for site location [mm]—derived from meteorological stations;
C rainwater catchment area;
R_{coef} run-off coefficient;
F_{coef} filter coefficient;
D_{col} defined period of collection: (e.g. 18 days/365 days = 0.05 chosen for assessing purpose).

ROOF TYPE	RUN-OFF COEFFICIENT
Pitched roof tiles	0.75–0.90
Flat roof smooth tiles	0.50
Flat roof with gravel layer	0.40–0.50

Scores are assigned according to:

SCORE	WATER RECYCLING
1	30 % of flushing demand has been achieved
2	45 % of flushing demand has been achieved
3	60 % of flushing demand has been achieved
4	75 % of flushing demand has been achieved
+1	Irrigation and external washing are provided by WR

Note: if the hospital does not present green areas and does not need irrigation. the extra point is given if more than the 90 % of flushing demand is supplied through water recycling.

Unit
[–].

Time reference
Annual survey.

Initial data availability
Fluxes measurement of grey/recycled water has to be provided. Values are compared with flushing demand, calculated previously on the base of the mean number of occupants, average usage of toilets and equipment specifications.

WATERCARE—low water use fittings

Definition
The indicator shows the usage of low water fittings for WCs, showers and taps.

Aim
To show up to which extent strategies for water saving are used inside buildings, considering taps, showers and WCs characteristics.

Description
Strategies for lowering potable water consumption are listed below: scores are obtained if strategies are applied to a significant amount of the hospital, at least 70 % of the total fittings installed.
The total score is given by the sum of the following points:

SCORE	LOW WATER USE FITTNGS
+2	WCs are dual flush, having an effective flush of 4.5 L or less. All urinals have individual presence detectors and work with ultra-low flushes or waterless. Points are also reached if in the indicator 'water recycle' 3 or more points are obtained
+2	Taps have maximum flow rate of 6 L/min for relative water pressure of 0.3 MPa and are equipped with sensors or timed automatic shut-off taps
+1	All showers have a measured flow rate that does not exceed 9 L per minute for a water relative pressure of 0.3 MPa, assuming a delivered water temperature of 37 °C; all baths have a capacity of 100 L to the overflow and each bath is fitted with a device that automatically stops the flow from the taps when the bath's maximum capacity is reached

Unit
[MPa], [1/min], [°C].

Time reference
Annual survey.

Initial data availability
Manufacturer's specifications about the as well as exact locations of installed equipment.

WASTECARE

Pre-requirements

- **Control and monitor**: Data has to be available at any moment: separate data for recyclable waste materials, separate data for hazardous waste and separate data for organic, compostable materials.
- **Waste separation**: separate and dispose the recyclable materials with adequate infrastructure: the collection system has to be well organized, dispersed and managed.

- **Site collection**: Specific collection area has to be dedicated to temporary collection waste collection: the site has to be located at least 20 m from building entrance and easily reachable for lorries. Hospital collection-site needs to be:
  - at least 2 m^2 per 1,000–5,000 m^2 of building net floor area;
  - minimum of 10 m^2 for buildings bigger than 5,000 m^2;
  - an additional 2 m^2 per 1,000 m^2 of net floor area where catering is provided. Recyclable waste compactor must be provided on-site for waste volume reduction to reduce transport costs and waste volume for storage on-site.

Definition
The criterion evaluates the outcomes of the undertaken actions in order to reduce hospital's waste production impact.

Aim
To minimize overall waste generation in hospitals (both general and infective) and to divert compostable, recyclable and hazardous waste from landfills.

Description
It considers the main strategies to reduce the impact of waste produced by the hospital: minimizing waste generation recycling, separating organic fraction, control of hazardous waste. That in accordance with the virtuous waste cycle: minimize, reuse, recycle, energy recovery, landfill. The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7):

$$\text{Wastecare} = \frac{(x \cdot \text{WG} + y \cdot \text{HW} + z \cdot \text{CW} + w \cdot \text{WR} + k \cdot \text{Co})}{5}$$

where:
WG Waste Generation (only for operative hospitals)
HW Hazardous Waste (only for operative hospitals)
CW Construction Waste (only for in-designing hospitals)
WR Waste Recycling
Co Composting

References
BRE Global Ltd 2010; USGBC 2011a; ITACA 2011; Pruss et al. 1999; Eurostat 2011.

WASTECARE—waste generation—only for operative hospitals

Definition

The indicator evaluates and rewards solutions undertaken by the hospital to reduce its waste generation, through minimization and reuse.

Aim

To minimize overall waste generation in hospitals.

Description

The indicator evaluates the overall amount of waste produced by daily working of the hospital. The main aim in waste production reduction is waste minimization directly at the source, where possible. Overall operational waste generation (non hazardous, hazardous, recyclable, etc.) is computed in terms of kilos of waste produced per day per bed.

$$WG = \frac{\sum \text{yearly operational waste}}{\text{n°bed} * \text{operational days}}$$

Score is assigned according to the waste generation:

SCORE	WG
1	37–42
2	32–37
3	32–27
4	27–21
5	<21

Fluxes are computed at the delivery points after treatment operations (e.g. sterilization, compaction).

Unit

[Kg/(bed*day)].

Time reference

Annual survey.

Initial data availability

Data are to be derived from records of waste fluxes (both for hazardous and non hazardous waste) and normalized by kg/day. Number of beds in the hospital has to be given.

WASTECARE—hazardous waste—only for operative hospitals

Definition

The indicator evaluates the amount of waste treated and disposed as hazardous.

Aim

To reduce the overall generation of hazardous waste in hospitals.

Description

Hospitals produce a certain amount of waste that cannot be treated as common solid waste since it can be infectious it has been in contact with infectious material, or, more generally, requires a specific disposing treatment depending on national regulations. Environmental and economic costs grow with the amount of waste treated as hazardous.

Scores are assigned according to the percentage of total waste produced treated and disposed as hazardous:

$$WG = \frac{\text{waste treated as hazardous}}{\sum \text{yearly operational waste}}$$

The total score is given by the sum of the following points:

SCORE	HW (%)
1	25–30
2	20–25
3	15–20
4	10–15
5	<10

Unit

Fluxes are in terms of [tons/year] or [m^3/year].

Time reference

Annual survey.

Initial data availability

Data about the amount of hazardous waste produced can be found on specific incinerator reports.

WASTECARE—construction waste—only for in-design hospitals

Definition
Indicator sets the path when dealing with construction waste, ensures adequately defined Site Waste Management Plan (SWMP) and sets certain targets of construction waste generation, which are supposed to be reached.

Aim
The indicator aims to reduce the future waste coming from construction phase, aiming to improve waste management efficiency of construction-site. Long term aim is to assure the reuse of the construction waste and its diversion from landfills.

Description
Construction waste has a great re-use potential in construction industry, but traditionally this waste was mainly put in the landfills. Main objective is to divert construction waste from landfill so operating time of landfills can be increased and economic damage avoided. Credits are assigned based on benchmark chosen (and normalized by the 100 m^2 of gross internal floor area), existence of SWMP. Scores are assigned according to:

SCORE	CONSTRUCTION WASTE
0	No benchmarks chosen and no SWMP prepared
1	Developed SWMP
+1	13.3 m^3/11.1 tones
+2	7.5 m^3/6.5 tones
+3	3.4 m^3/3.2 tones
+1	Waste separation is going to be performed on-site and waste recycling/ reuse where possible

Note: Waste included in the benchmarks is waste from excavation, demolition and waste generated during regular construction works. Presence of SWMP and target for waste generation is important. Waste generated does not have to be necessary used on-site, it can be used on other sites, transported back to supplier or salvaged for further use, but it cannot be sent to landfill otherwise no credits has been assigned.

Unit
[–].

Time reference
Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
In the design stage data can be derived from project documentation, which has to prove that SWMP has been designed and benchmarks have been chosen.

WASTECARE—waste recycling

Definition
The indicator evaluates results achieved in separating and collecting recyclable waste.

Aim
To enhance on-site recyclable waste separation and therefore to divert recyclable materials (such as paper, plastic, glass, aluminum, batteries, etc.) from landfills or energy recovery.

Description
The indicator presents two different definitions.
If the structure is already operative, the indicator is defined as the ratio between the amount of separated recyclable materials respect the total mass of non-hazardous hospital waste produced. Organic waste is not computed among the recyclable materials since another indicator is made to consider its specific recovery.

$$WR = \frac{\text{Recycled waste}}{\text{operational non haz. waste}}$$

If the hospital is under design/construction Project team has to be able to demonstrate that the collection system is well designed (as stated in prerequisites) with bins well dispersed labelled and place for storage well designed. Scores are given if this requirements are achieved (OH = Operative Hospitals; IDH = In-Design Hospitals):

SCORE	WR OH (%)	SCORE	WR IDH
1	8–16	0	Required infrastructure is not predicted
2	16–24	+1	Clearly labelled collection bins, in chosen colour has been planned, covering all public areas (outside and inside)
3	24–32	+1	Routes for collection and transportation (from the bins) of recyclable waste to the main storage has been predicted
4	32–40	+2	Temporary storage has been defined according to prerequisites described in the main page of the indicator waste
5	>40	+1	Compacter has been planned on the temporary storage site

Unit
Fluxes in terms of [Tons/year] or [m^3/year].

Time reference
Annual survey.

Initial data availability
Waste fluxes records.

WASTECARE—composting

Definition
This indicator evaluates efforts done to collect and separate organic waste.

Aim
To divert from landfills all organic non-hazardous compostable material (food, waste, garden waste, etc.), which is normally coming from hospital operation, employing composting.

Description
Organic waste is mainly produced by kitchen and gardening maintenance. Even though data varies from structure to structure, food waste is one of the main voice in hospital waste composition. Typically hospital canteen is managed by an external company, but it may happen that its waste disposal is made with others waste produced by the hospital.
Credits are assigned based on:

SCORE	COMPOSTING
+4	Organic waste produced by the kitchen is collected in separated way and disposed in a different way (composted in internal plant or in an external one) OR the external company to which is committed the canteen and the disposal of its waste certifies the different collection of organic waste produced
+1	Green waste derived by gardening maintenance is collected and treated differently with respect to non hazardous waste produced by the hospital (composted in internal plant or in an external one)

Note: if no green areas are present in the hospital scores available for different disposal of organic waste from kitchen are 5.

Unit
[–].

Time reference
Annual survey.

Initial data availability
Data are to be derived from waste management, agreements with external companies private or public utilities.

COMBINED HEAT and POWER

Pre-requirements

- **Exergetic convenience**: CHP is compared with separated generation of heat and power. Given a certain output, the higher is the exergetic efficiency of CHP compared to separate production, the better it is. Once the plant is working, the constraint

$$(\eta_{exCHP} - \eta_{exsep})/\eta_{exCHP} = \text{PES (Primary Energy Saving)} > 10\,\%$$

Has to be satisfied over a year. To define the $\eta_{ex,sep}$ the average efficiency of the national power system production and the thermal average national efficiency for industrial use are to be considered.

Definition
The criterion evaluates the convenience of CHP technology and the amount of energy produced through cogeneration.

Aim
To reward hospitals which exploit as much as possible a convenient CHP plant in order to supply the contemporaneous needs for electricity and thermal energy.

Description
CHP produces both electricity and energy for thermal needs at different temperatures. If trigeneration is present also the hot fluxes for absorption chillers must be accounted.
To better compare different fluxes the indicator is defined as the ratio between the exergy need supplied by CHP and the exergy related to the above mentioned fluxes.

$$CHP = \frac{(Ee + \sum Et * \theta)_{CHP}}{(Ee + \sum Et * \theta)_{tot}}$$

where:
Ee electric energy;
Et*θ thermal energy multiplied by Carnot factor to turn it into exergy form in order to make a fair comparison with electric energy. The Carnot factor must be referenced to sizing temperature T_{winter} and T_{summer} for hot and cold production respectively.
Scores are assigned according to:

Score	CHP (%)
1	>15
2	30–45
3	45–60
4	60–75
5	>75

References
European Parliament and the council of the European Union 2004; Galliani 2008; Midwest CHP Application Center 2007.

MATERIALS and RESOURCES—only for in-design hospitals

Definition

Assessment of the quality and the reduction of used resources during construction phase. The aim is to cut the global impact due to the realization of the building, thorough the selection of short chain materials, resulting from recycling processes, not-toxic materials, characterized by a predefined recovery destination.

Aim

The indicator try to minimize the problem linked with the consumption of resources, it is mainly due to materials used in the construction phase of the building. It is not just considered the specific problem due to the construction, but also the future problems due to the disposal phase with the problem of materials disposal. Is incentivized the recycling and the recyclability or the possibility to reuse some components to decrease the overall use of resources.

The TVOC indicator is finalized to sensitize to the design of buildings which are not illness generative is so considered the phase of material selection particularly for the finishing materials.

Description

It considers different problems connected with technological choices, using an optic from cradle to cradle. The use of sustainable politics in production building phase ere incentivized, besides an assessment of possible future scenarios is considered, therefore are favoured politics which don't neglect the rooms healthiness. The indicator evaluate with a percentage score from 0 (insufficient) to 100 % (excellent) the effectiveness of the material selection phase (refer to the values reported in Fig. 4.7):

$$\mathrm{M\&}R = \frac{(\mathrm{x} \cdot 0\,\mathrm{km} + \mathrm{y} \cdot \mathrm{Re} + \mathrm{z} \cdot \mathrm{RC} + \mathrm{w} \cdot \mathrm{TVOC})}{5}$$

where

0 km	0 km materials
Re	Recyclability
RC	Recycled Components
TVOC	VOC and Materials toxicity

References

BRE Global 2010; ITACA 2011; USGBC 2011a.

MATERIALS and RESOURCES—0 km materials—only for in-design hospitals

Definition
Evaluation on the origin of materials used, is believed that the closest is the place of extraction or production to the construction yard more sustainable is the overall building process.

Aim
The indicator aim to foster the use of local material to reduce the environmental impact of transports, minimizing energetic costs and also promote local economy (through the promotion of companies which favourite the recycling and the reduction of the production of waste).

Description
The indicator assess with a score from 0 (insufficient) to 5 (excellent) the presence of '0 km materials' evaluating the percentage of material (assessed in kg) coming from a distance of 350 or 150 km (between production site to building site).
Scores are assigned according to:

SCORE	0 km MATERIALS
0	0 % of materials coming from a distance of 350 km
1	10 % (or more) of materials coming from a distance of 350 km
2	20 % (or more) of materials coming from a distance of 350 km
3	30 % (or more) of materials coming from a distance of 350 km
4	10 % (or more) of materials coming from a distance of 150 km
5	20 % (or more) of materials coming from a distance of 150 km

Unit
[km].

Time reference
Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
Bills of materials to evaluate de distances, bill of quantities to assess the quantity of materials.

MATERIALS and RESOURCES—recyclability—only for in-design hospitals

Definition
Assessment of recyclable components among building materials: is believed that the selection of recyclable materials with up cycling outcomes (conversion of the material in product with the same quality of the initial one) gives additional value to the sustainability of the project.

Aim
To reduce the use of row materials, thorough the use of recycled materials, easily separable materials and building procedures that allow selective demolitions. Reducing wastes generated by demolition.

Description
The indicator assess with a score from 0 (insufficient) to 5 (Excellent) the percentage of materials used in the construction which are recyclable thorough simple procedures, meaning disassembly of dry works, stratigraphy composed by a limited number of layers, easy removal of mortars and glues or crush of indivisible materials.
Scores are assigned according to:

SCORE	RECYCLABLE MATERIALS
0	No use of any recyclable material
1	Up to 10 % weigh in the total weigh of the building
2	Up to 20 % of weigh in the total weigh of the building
3	Up to 40 % of weigh in the total weigh of the building
4	Up to 60 % of weigh in the total weigh of the building
5	More than 60 % of weighs in the total weigh of the building

Unit
[kg].

Time reference
Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
Contract performance of building materials, technical specifications building phase specifications to evaluate the recyclability of each stratigraphy. Bill of quantities to assess the quantity of materials.

MATERIALS and RESOURCES—recycled components—only for in-design hospitals

Definition

The indicator assess the presence of recycled material used in the building phase, it incentivizes a design that is directed toward a decreasing use of not renewable resources. The use of recycled materials takes to a decrease of wastes produced in dismantling process, also the overall decreasing in energy consumption is achieved, energy considered as embodied energy due to productive processes of materials. The assessment takes into account the presence of percentage of recycled material because is difficult for many type of materials to have the whole producing process based on recovered row materials.

Aim

Sensitize to a design that incentivize a sustainable selection of finishing materials, is rewarded the selection of materials with less organic materials that can disperse VOC, as timber or natural derived materials.

Description

The indicator assess the percentage of materials used in the construction which are characterised by the presence (for a part or the whole) of content derived by recycling processes. Score is assigned according to:

SCORE	RECYCLED COMPONENTS
0	0 % of materials characterized by content derived (for a part or the whole) by recycling process
1	5 % of materials derived by recycling process
2	10 % of materials derived by recycling process
3	15 % of materials derived by recycling process
4	20 % of materials derived by recycling process
5	25 % of materials derived by recycling process

Unit

[kg].

Time reference

Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability

Contract performance of building materials technical specifications to evaluate the recyclability of each stratigraphy. Bills of quantities to assess the quantity of materials.

MATERIALS and RESOURCES—tvoc and materials toxicity—only for in-design hospitals

Definition
The indicator analyses the problem created by the presence of compounds or elements in the indoor air which can create discomfort or problems on the health of room users. Concentration analysis is used, to compare values to threshold given by laws; the material selection must be oriented toward sustainability not just to achieve benchmarks but also the improvement of the performance by this point of view.

Aim
Sensitize to a design that take into account a sustainable selection of finishing materials, the incentive is related to the selection of materials with low presence of organic materials that could disperse VOC, for example timber or natural derived materials.

Description
The indicator evaluates the presence of materials that in operative phase do not release into the indoor environment Total Volatile Organic Compound (TVOC). The assessment evaluates the indoor directly measurable concentration after 28 days of installation of the material.
Scores are assigned according to:

SCORE	TVOC and MATERIALS TOXICITY
+1	Using of materials for **floors** that take into account a reduction of TVOC for at least 70 % of the total surfaces
+1	Using of materials for **walls** with a reduction of TVOC for at least 70 % of the total surfaces
+1	Using of materials for **ceilings** that guarantee a reduction of TVOC for at least 70 % of the total surfaces
+1	Using **furnitures** and **appliances** that guarantee a reduction of TVOC for at least 70 % of the total surfaces
+1	Specific studies about pollutants during the design phase

Unit
[$\mu g/m^3$].

Time reference
Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
Technical specifications, bill of quantities for the finishing materials.

UNCONVENTIONAL SOURCE SUPPLY

Pre-requirements

- **E-team**: going beyond art. 19, Ministerial directive 10/91 (Italian Parliament 1991) must be constituted an high skilled and multidisciplinary Energy team to better analyze all the different aspects in which energy is involved.
- **Feasibility study**: the main feature of renewable technologies is the dependence on intermittent sources. This is why the different solutions are not equivalent since they depend on the boundary conditions of the hospital's site. Before deciding which solution is the best one for the hospital the Energy Team must conduct an Energy/Economic analysis to determine which is the most efficient way to supply hospital's needs.
- **Compliance to Legislative decree n. 28**, for buildings under construction from 05/2012, (Presidency of the Italian Republic 2011): hospitals must cover 30 % of cooling heating and hot water need by using renewable energy sources (over a year). Moreover 60 % of hot water must be produced by renewable energy sources.

Definition
The criterion evaluates the percentage of the energy need covered by renewable energy sources.

Definition
To promote the exploitation of renewable energy sources for thermal and electric needs and to stimulate the adoption of innovative technologies.

Description
This criterion is focused on technologies which can exploit Renewable Energy Sources (RES). The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7):

$$\mathrm{USS} = \frac{(x \cdot \mathrm{DHW} + y \cdot \mathrm{HC} + z \cdot \mathrm{El})}{5}$$

where
DHW Domestic Hot Water
HC Heating and Cooling
El Electricity

References
Italian Parliament 1991; Presidency of the Italian Republic 2011.

UNCONVENTIONAL SOURCE SUPPLY—domestic hot water

Definition
The indicator evaluates the fraction of Domestic Hot Water (DHW) need covered by renewable energy sources.

Aim
To reward hospitals which exploit Renewable Energy Sources (RES) to supply DHW needs as much as possible and to stimulate energy production from renewable sources.

Description
The object of evaluation is the amount of energy need covered exploiting RES over the total energy need for DHW.

$$f = f_{district\ Heating} + f_{heat\ pumps} + f_{Biomass} + f_{solar\ collector}$$

The parameter f is the sum of all the energy fractions corresponding to the different technologies exploited to satisfy thermal needs. Each fraction is defined as the ratio between the amount of DHW produced by the specific technology and the total amount of DHW.
If CHP plant is present and its Primary Energy Saving (PES) is higher than 10 % (see **CHP indicator**), the part supplied by the CHP must be deducted from the DHW need.
The term 'heat pump', includes all the different technologies (air/air, water/air, water/water, geothermal absorption, etc.) which can be used to produce DHW. If the score of **Electricity indicators** is lower than 5, the thermal flux considered as produced from renewable source is the one extracted from the source (ground water, air). Otherwise is the heat introduced in the DHW flux. Scores are obtained according to the following:

SCORE	f (%)
1	<10
2	10–20
3	20–30
4	30–40
5	>50

Note: for buildings under construction from May of 2012 a value of 0 has to be assigned to hospitals that reach a value of *f* lower than 4.

Unit
All the *f* fractions are in terms of [(kWh/kWh)/year].

Time reference
Annual survey.

Initial data availability
Data on meters and counters of boilers and other systems (or estimation).

UNCONVENTIONAL SOURCE SUPPLY—heating and cooling

Definition
The indicator evaluates the fraction of heating need covered by renewable energy sources and it considers the possibility to exploit innovative solutions also for cooling needs.

Aim
To reward hospitals which exploit Renewable Energy Sources (RES) for heating and cooling as much as possible and to stimulate energy production from renewable sources.

Description
The object of evaluation is the amount of energy produced exploiting RES over the total amount of energy needed for heating and cooling.

$$f = f_{district\ Heating} + f_{heat\ pumps} + f_{Biomass} + f_{solar\ collector}$$

The parameter f is the sum of all the energy fractions exploited to satisfy thermal needs each one corresponding to a different technology. Each fraction is defined as the ratio between the amount of heat produced by the specific technology and the total amount of heat required by the structure.
If a CHP plant is present and its Primary Energy Saving (PES) is higher than 10 % (see **CHP indicator**) the part supplied by the CHP must be deducted from the heating/cooling needs.
The term 'heat pump', includes all the different technologies (air/air, water/air, water/water, geothermal absorption, etc.) which can be used to grant heating/cooling. This technology is able to exploit renewable energy sources both for heating and cooling. If the score of **Electricity indicator** is lower than 5, RE produced by heat pumps is the one extracted by the source (ground water, air). Otherwise heating/cooling flux produced from RE is the one introduced in the conditioned space.
Scores are assigned according to:

SCORE	H/C (%)
1	5–10
2	10–15
3	15–20
4	20–25
5	>25

Unit
[kWh/kWh].

Time reference
Annual survey.

Initial data availability
Data on meters and counters of boilers and other systems (or estimation).

UNCONVENTIONAL SOURCE SUPPLY—electricity

Definition
The indicator evaluates the fraction of electric need covered by renewable energy sources.

Aim
To reward hospitals which exploits Renewable Energy Sources (RES) for electric needs as much as possible and to stimulate energy production from renewable sources.

Description
The object of evaluation is the amount of energy produced by exploiting RES over the total amount of electric energy needed.

$$f = f_{PV} + f_{external\ Agreement}$$

The parameter f is the sum of the fractions of total power supplied by PV plants and by external agreements that certify energy used by the hospital as produced from renewable sources. If other renewable sources are used to produce electricity, they can be computed as external agreements since this indicator evaluates only the energy output of any solution.
If CHP plant is present and its Primary Energy Saving (PES) is higher than 10 % (see **CHP criterion**) the fraction supplied by the CHP must be deducted from the total electric needs.
Scores are assigned according to:

SCORE	El (%)
1	<15
2	15–20
3	20–25
4	25–30
5	>35

Unit
All the f fractions are in terms of [(kWh/kWh)/year].

Time reference
Annual survey.

Initial data availability
Data can be collected from meters of PV plants and external providers reports.

URBAN PLANNING

Definition
The criterion evaluates the localization of the hospital, dealing with quality and environmental impact, site accessibility and landscaping.

Aim
To analyze the context and the site where the hospital is located the transport system and the connection to the city, the accessibility of the building and the possible introduction of vehicles with unconventional fuels or car sharing for patient transport.

Description
The criterion needs the observation and analysis of the context in which the hospital is built; it is necessary to identify the exogenous pressure elements that influence the hospital activities. Moreover impact due to the insertion of a new structure in a preexisting context is considered. The final credit is the result of a weighted average of the scores obtained in each indicator (refer to the values reported in Figs. 4.6 and 4.7):

$$\text{Urban planning} = \frac{(x \cdot TA + y \cdot ELI + z \cdot Ri + k \cdot SP)}{5}$$

where:
TA Transport and Accessibility
ELI Environmental and Landscape Impact
Ri Risks (only for in-designing hospitals)
SP Site Physics (only for in-designing hospitals)

References
BRE 2010; Capolongo et al. 2011; ITACA 2011; USGBC 2011a, b; Minister of Public Works 1968; Rossi Prodi and Stocchetti 1990.

URBAN PLANNING—transport and accessibility

Definition
Is assessed the effectiveness of paths to accede to the hospital.

Aim
To verify the presence of a good connection of the transports with the city, cycling routes, use of vehicles with eco-fuels or car sharing methods.

Description

It evaluates the accessibility to the hospital for workers patients and visitors considering different transports (car, bus, bicycle, ambulance) and the quality of paths; it also verifies the easiness to reach the hospital. The indicator assess also the quantity of parkings and the differentiation between the workers and visitors ones. Score is given for:

SCORE	TRANSPORT and ACCESSIBILITY
+1	Localization of the building within a distance (from a main entrance) of 1,000 m by foot, from a railway station a helicopter landing field, port or a light subway existing or planned
+1	Localization of the building within a distance (from a main entrance), of 250 m from one or more public transport stop or a shuttle system provided by the hospital. The point is scored only if the regulations on accessibility for disabled are guaranteed
+1	Presence of cycle routes to reach the hospital and of covered spaces and security systems to store bicycles for at least 10 % of users
+1	Car sharing service for the hospital users equipped with low emission vehicles or with vehicles provided with unconventional fuels
+1	Parking capacity sized in respect to one of these two methods • Parkings for not less than one s.m. every ten cubic meters; • Ponter study (Rossi Prodi 1990), parking spaces (p.s.): – p.s. for visitors: 1 p.s. every 3-5 patients; – p.s. for patients: 5 p.s. every doctor; – p.s. for nurses: 1 p.s. every 3 nurses; – p.s. for doctors: 1 p.s. every 1.5 doctor; – p.s. for emergency: 10 p.s.

Unit

[m].

Time reference

Annual survey.

Initial data availability

Cycle paths, public transports routes; external hospital plan.

URBAN PLANNING—environmental and landscape impact

Definition

The indicator evaluates the quality of the master plan part which focuses on the outdoor area of the hospital.

Aim

To minimize the impacts of the building and to analyze the environmental quality of the hospital and its surroundings.

Description
It defines the footprint of the building the presence of accessible green areas and integration of the hospital in the context.
Scores are assigned according to:

SCORE	ENVIRONMENTAL and LANDSCAPE IMPACT
1	The ecological footprint is not changed by the action
2	The ecological footprint is decreased by the action
+1	The operation increases the accessibility conditions to green areas for users (increased surface of green areas such as gardens and parks or increasing of existing green presence thorough ponds, rocky gardens, etc.)
+1	The operation increases the volume of the building and this addition is architectonically integrated or the operation improves the external quality of the building
+1	Measures that aim to minimize the soil waterproofing through the minimization of asphalted surfaces, or the use of semi permeable surfaces or green roofs are taken

Unit
[–].

Time reference
Annual survey.

Initial data availability
Direct assessment in site.

URBAN PLANNING—risks—only for in-design hospitals

Definition
The indicator defines the best site choice, allowing the minimisation of some risks due to context site by an environmental and urban optics.

Aim
To avoid possible discomfort for patients and workers due to errors in the site choice. Good score means a design oriented on these issues.

Description
The risk absence is necessary in the hospital designing process, very often risks may come directly from the context where the building is situated. Contextual risks can be sometimes minimised through the right localization choice, putting the building in less hazardous areas. In other cases hazardous conditions are developed in a broad territorial area, so the indicator should assess how much are effective the contrast solutions adopted

in the designing process. The evaluation method is characterized by a score structure considering the attribution of points due to the achievement of benchmarks. Scores are assigned according to:

SCORE	RISKS
1	If the building is between 150 and 230 m to an electromagnetic pollution creator such as a high voltage electric line or a communication antenna
2	If the building is farther than 230 m to an electromagnetic pollution creator
+1	Where are adopted proceedings finalized to minimize the hydro geological risk
+1	If are adopted innovative systems to avoid seismic problems
+1	If the industrial plants hazardous for the kind of production present in the contextual areas have adopted procedures to minimize risks more restrictive than what imposed by law

Unit
[–].

Time reference
Calculated in the design phase remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
Direct measurements, statistical values, thematic cartography.

URBAN PLANNING—site physics—only for in-design hospitals

Definition
Quantitative physical performances due to master plan choices.

Aim
The indicator aim is to assess the choices on building localization, materials of external finishing and discomfort issues mitigation.

Description
The indicator assesses the designing choices at master plan level, it gives threshold linked to the performances on thermal pollution caused by the excessive overbuilding, material choice, acoustic insulation regarding contextual noises and evaluate the daylight availability.

Scores are assigned according to:

SCORE	SITE PHYSICS
0	If the average energetic reflection factor (rm) xf external area surfaces is higher than 70 %
1	If the average energetic reflection factor (rm) of external area surfaces is between 50 and 70 %
2	If the average energetic reflection factor (rm) of external area surfaces is lower than 50 %
+1	If the intake level calculated near the façade (L_{2eq}) is lower than 45 dB $A_{diurnal}$—35 dB A during night
+1	If the percentage of glazed surfaces exposed, during winter to direct solar radiation are between 30 and 15 %
+1	If the percentage of glazed surfaces exposed, during winter to direct solar radiation are higher than 30 %

Unit
[–].

Time reference
Calculated in the design phase, remains valid until further modifications. Every modification implies the evaluation upgrading.

Initial data availability
Direct assessment and evaluation in the designing phase.

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Chapter 5
Testing the SustHealth Evaluation System

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Abstract The SustHealth evaluation system was successfully experimentally tested through its application to an existing operative and a new hospital located in the Italian region of Lombardy. The whole evaluation was carried out in no more than 2 months, realizing interviews, questionnaires, on-site inspections and measurements. Every criterion demonstrated to be easily evaluable thanks to its clarity, objectivity and to data availability, providing interesting results, in terms of both emerging criticalities and possible measures for improvement. The developed tool has therefore demonstrated to be easy-to-use, simple and effective. It could be further improved considering its application to a higher number of hospitals, both in Italy and abroad, deepening the understanding of the surrounding international scenario. Moreover, it could also concur in the realization of a national database of healthcare structures, useful both for managers and patients.

Keywords Scores and results · Existing hospital · New construction hospital · Improvement · Effectiveness/cost · Outcomes · Best practices · Going beyond

System Testing in an Existing Operative Hospital

The developed evaluation system was tested in an operative hospital in the Italian region of Lombardy, whose cannot be named due to privacy concerns. The structure is located close to a city park, in a urban area with few infrastructures and public services. It is quite close to an important public transport station and to

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the ring road. The hospital was designed in the 60's by an Italian architect, but it started to work in the late 1970s. The structure is constituted by three buildings linked to form a mono-block structure, which, during the decades, was further enlarged. The hospital is 10 floors tall, plus two more basement floors, for a total floor area of 80,000 m^2. Inpatient areas are mainly characterized by a central corridor, with patient rooms arranged on both sides.

The hospital is accredited by the Italian NHS and has approximately 600 inpatient beds (including over 80 beds for day hospital) serving a catchment area of approximately 500,000 citizens. Overall, the structure employs over 1,800 people: approximately 300 doctors, 700 nurses, 500 support staff, 30 other medical personnel and 275 technical or administrative staff. The structure hosts the students enrolled in the faculties of Medicine, Surgery and Dentistry of the local University.

Results and Sustainable Strategies

The system was tested during the summer season of 2012. The evaluation was possible thanks to staff interviews, users' surveys and the study of available documentation in the technical offices. All the monitored fluxes (in terms of energy, waste and water) refer to 2011, the latest available data.

The tested hospital reached a global evaluation of 38/100 (insufficient). The score was given by weighting the points obtained in the three macro-areas of sustainability: the best result was gained in the economic area, with a score of 52/100 (almost sufficient), whereas the worst result was obtained in the environmental one, with a score of 8/100 (extremely insufficient). Social sustainability was evaluated with a total score of 25/100 (insufficient).

The figure shows how many points were obtained for each criterion. Score ranges are represented through five concentric circles: red 0–20 (or pre-requirements not fulfilled); orange 20–40; yellow 40–60; light green 60–80; green 80–100.

The criteria of each macro-area are plotted in bubble diagrams showing the obtained scores and the solutions prioritization. Priority must be given to effective solution, which allow to improve the overall performance of the hospital with low costs (both economic and in terms of time) and with low impact on the structure. The bubble dimension is representative of the weight of the criterion (Fig. 5.1).

Economic Sustainability

Among all the macro-areas the economic one gives the most satisfying result: 52/100 (Fig. 5.2).

The hospital obtained an average score thanks to the respect of regulations and common standards. However it lacks sometimes of coordination among different departments and of proactive spirit. Employees should be free and encouraged to give their own contribution promoting in this way also the best organization of work flow.

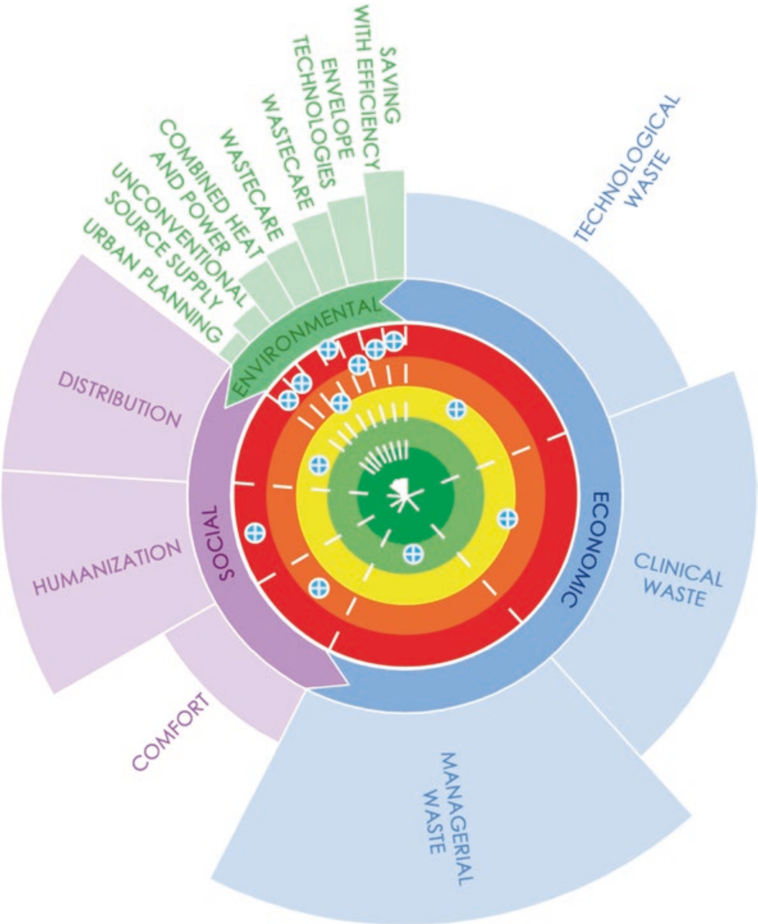

Fig. 5.1 The results in an operative hospital

Fostering improvements in the managerial area would give remarkable results with no waste of resources, since only a re-organization of the available ones is needed. Acting on technological issues facilitates communication, but it requires more funds to renew hardware facilities; measures in the clinical area are cheaper, but they do not guarantee evident achievements in the short term, due to stochastic processes.

Social Sustainability

The social macro-area scored the 25/100.

Toward the implementation of social sustainability it is suggested to act first of all on *Humanization* issues, some of the most improvable with low costs and few

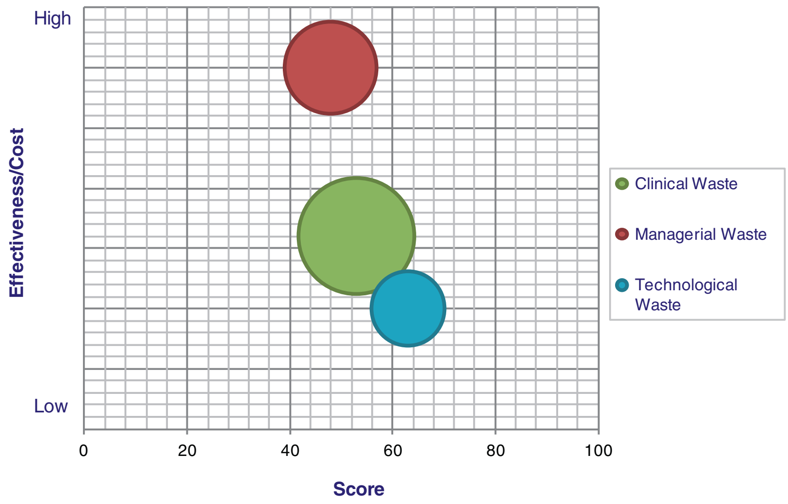

Fig. 5.2 The results of Econonic Sustainability in an operative hospital

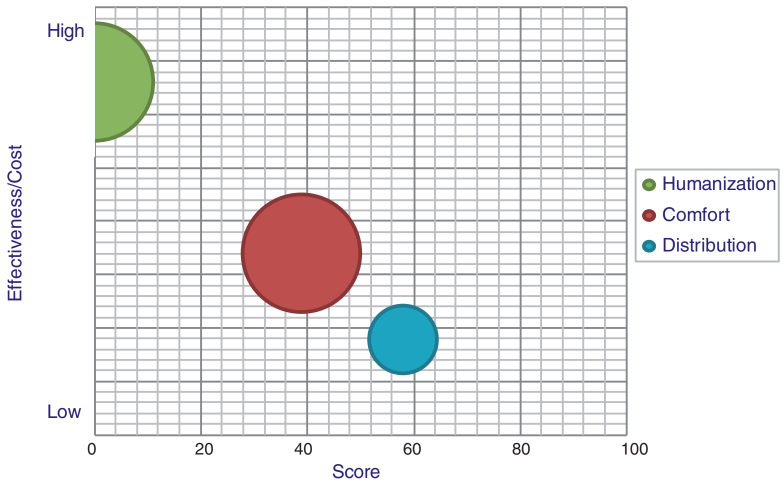

Fig. 5.3 The results of Social Sustainability in an operative hospital

interventions (people involvement, implementation of hospital services, introduction of recreational activities); of course, it is necessary to do everything possible to adapt the hospital to its pre-requirements (Fig. 5.3).

On the contrary, intervention concerning *Distribution* issues is very difficult because of the old fashioned structure that does not allow to implement in a satisfying way solutions toward flexibility and paths' reorganization. Regarding *Comfort* criterion, it has been decided to take into account the possibility to act with soft interventions in terms of lighting and acoustics.

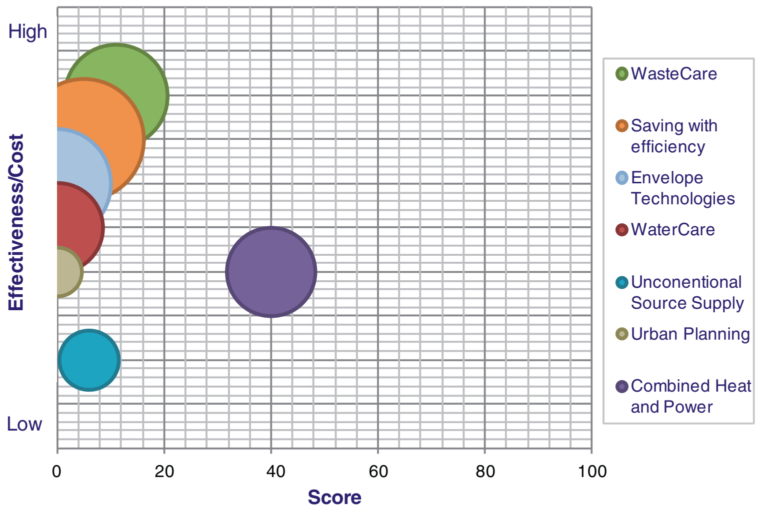

Fig. 5.4 The results of Environmental Sustainability in an operative hospital

Environmental Sustainability

The environmental sphere obtains an insufficient result: 8/100. Environmental sustainability presents some critical issues: pre-requirements are slightly satisfied and sometimes are even not fulfilled. It is suggested to firstly implement solutions that require users' involvement (Fig. 5.4).

Envelope technologies allow to appreciably reduce energy consumption but it is secondary with respect to users' awareness. The hospital presents relevant possibilities in terms of sustainable water management but it requires significant changes in the structure. The implementation of energy supply from unconventional sources requires time and high investment costs.

System Testing in a New Construction Hospital

The Hospital corporation, whose cannot be named due to privacy concerns, was founded in 1998 and it was built in the last decade. It is a general hospital serving a catchment area of approximately 500,000 citizens and it has approximately 550 inpatient beds.

The structure is technologically advanced but at the same time pleasant. It consists of low-rise buildings for a floor area of 80,000 m^2 and it is divided into departments that ensure spatial contiguity between areas of greater interaction. The spaces destined for hospitalization, diagnosis and treatment constitute 50 % of the total area. The remaining 50 % is made up of areas that host services for the public and the commercial spaces.

The project is articulated with a tight system that defines a central closed courtyard, and some open courtyards, looking towards the city and the landscape, to confirm and affirm the status of new urban centrality. The different appearance of the courts articulates in relation to the various sectors of reference, in contrast to the apparent homogeneity of the system. Clear differences are made by elements such as a space dedicated to theater and a meeting place connected to the convention center.

Results and Sustainable Strategies

The system was tested during summer 2012. The evaluation was possible through users' surveys, staff interviews and the study of available documentation in the technical offices.

The tested hospital reached a global evaluation of 61/100 (almost sufficient) (Fig. 5.5).

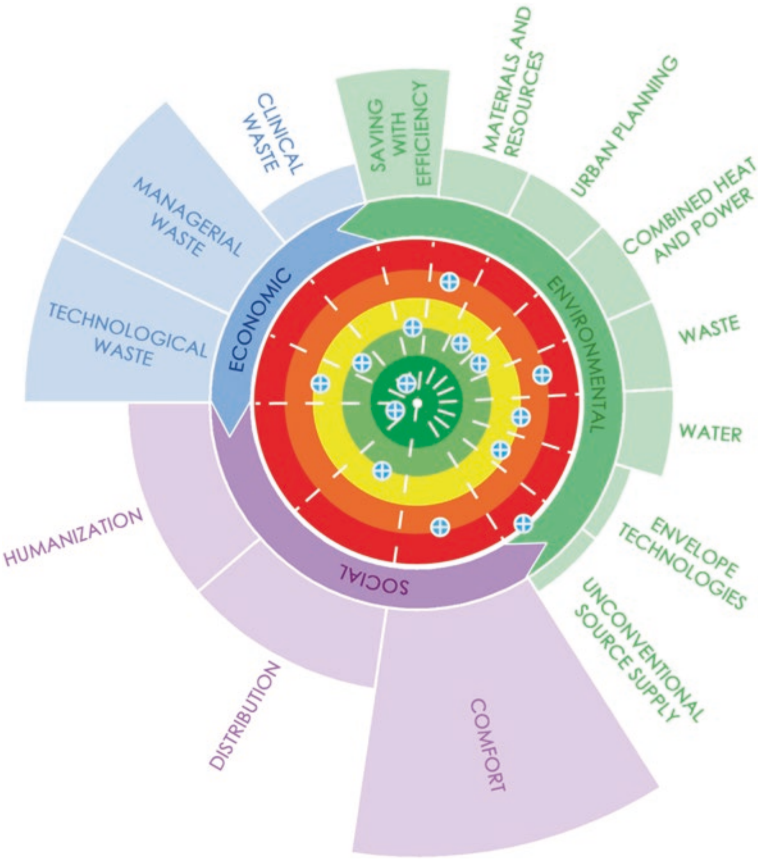

Fig. 5.5 The results in a new construction hospital

The hospital seems to be quite sustainable in the economic area, where it reaches almost 70 % while it's halfway in the environmental and social side. These results can give a precise idea of the sustainability state of the hospital. They have been re-expressed as priorities of intervention to change the hospital during its designing phase and to make it more sustainable.

The score was given by weighting the points obtained in the three macro-areas of sustainability: the best result was gained in the economic area, with a score of 68/100 (sufficient), whereas the worst result was obtained in the environmental one with a score of 45/100 (insufficient). Social sustainability was evaluated with a score of 47/100 (insufficient).

It seems so quite clear that for the Hospital, despite the macro-areas results, it would be most important and effective to work to improve the environmental aspects since they represent almost 60 % of the improvements that can be done to achieve the maximum score.

The results of the evaluation of each criterion can be resumed in the bubble chart. Each criterion then contributes according to its weight, and so its importance, to the final score of each macro area.

Economic Sustainability

Among all the macro-areas the economic one provides the most satisfactory result: 68/100.

The criterion Managerial Waste turns out to get the best score thanks to the excellent results obtained in the indicators *Staff Qualification and Education* and *Build in Quality*. In fact the measures put in place in order to train the personnel working optimization of the hospital work process evaluated, and Build in quality process, in which the degree of innovation pursued by the project fielded in reference to standards and benchmarks assessed (Fig. 5.6).

Environmental Sustainability

The environmental sphere reaches an insufficient result: 47/100. Failure to achieve sufficiency by the newly constructed building is due to the fact that the hospital was not designed with the goal of maximizing environmental performance. This shows how the presence of control tools to apply sustainability as evaluation step in the project could become an instrument of education to sustainable design (Fig. 5.7).

So *Technological performance* is the criterion about which the most could be improved; simply working on it can enhance significantly the overall sustainability of the healthcare structure.

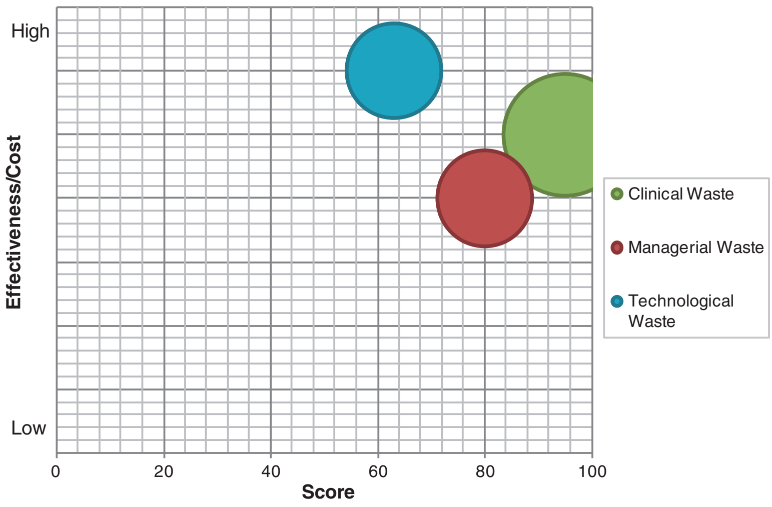

Fig. 5.6 The results of Economic Sustainability in a new construction hospital

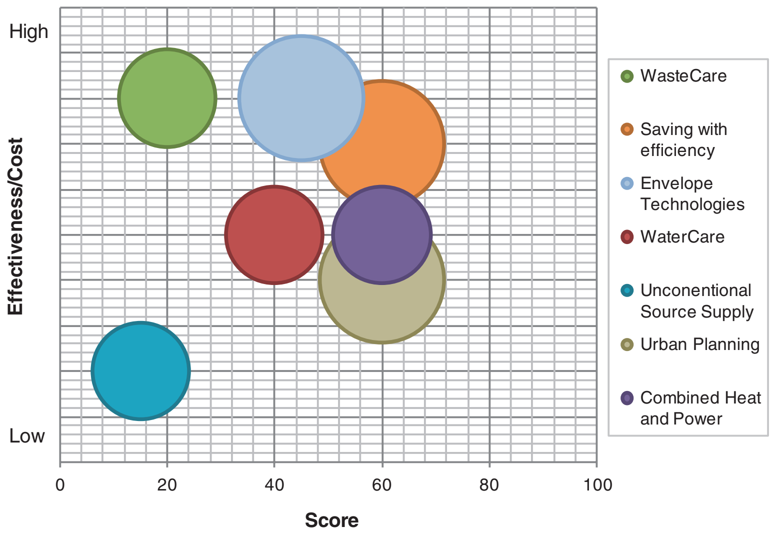

Fig. 5.7 The results of Environmental Sustainability in a new construction hospital

Social Sustainability

Analyzing the results obtained for the newly constructed hospital, it is important to emphasize that the final value is highly affected by the low result in the *Comfort* criterion, which is very influential. The low score is due to the fact that the project

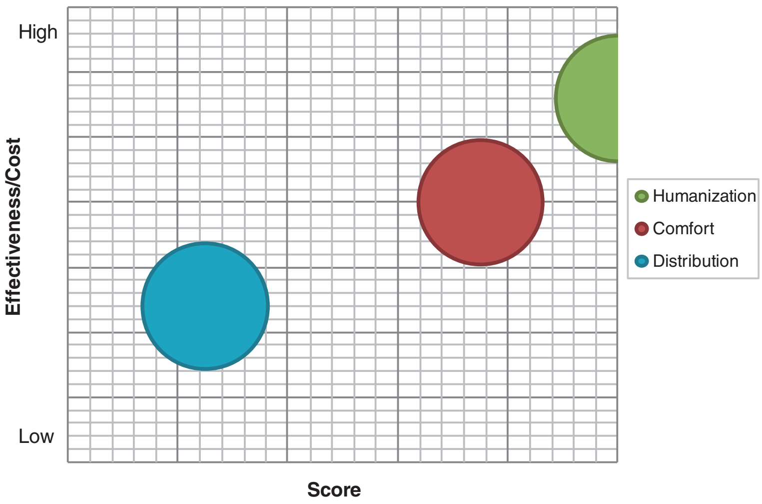

Fig. 5.8 The results of Social Sustainability in a new construction hospital

team has preferred to carry out the minimum requirements of the law about environmental performance without further improvements, to the disadvantage of the comfort of the hospital population (Fig. 5.8).

Results Discussion

The test of the evaluation system on two Italian hospitals has shown how easy-to-use and handy the developed tool is. Non-experts of the specific field can indeed also easily evaluate the performance of the hospital. The evaluation system was wholly applied in about 2 months: a relatively short period, especially considering how the questionnaires must be submitted to users and then analyzed in order to allow the Direction to understand what areas need to be improved. Positive results concerning the SustHealth system have been obtained because of its easiness of application and capability to highlight areas where sustainability is more likely to be achieved.

The tool goes beyond the conventional schemes of evaluation, mostly related to environmental aspects, and considers all the facets of sustainability in a very multidisciplinary way. A fundamental position is assigned to the economic aspects, to establish the primary role covered by an effective management. Social sustainability becomes relevant to state the centrality of the user (both patients, visitors and staff) in a specific and ticklish context such as an operative hospital. This aspect is mainly evaluated by means of questionnaires, through which qualitative and emotional indications are translated into quantitative measurements, which can be used for the hospital's performance improvement. The tool does not just give a complete evaluation of the hospital in terms of sustainability, but it also produces a prioritized list of aspects, of which the performance must be improved if a low score is obtained.

The weights of the different elements composing the evaluation tool (macro-areas of sustainability, criteria and indicators) were determined through the ANP, which requires experts' opinion and extensive knowledge about hospitals. However, the ANP method cannot prescind from the personal influences on the objective opinions, which are caused by the specific field of study (or work) and by the involved expert's own background. This represents the main feature of the ANP method and allows to include the human factor into the developed tool, so important when social themes are to be discussed. This though may also present some drawbacks such as difficulties, standstills or high inconsistencies in weights establishment.

The tool's development has shown how complex and diverse the reality of a hospital can be. Its required functional and operational continuity necessitates a high level of coordination between all the involved actors in order to ensure the fulfillment of its fundamental duties. If studied as a closed system from a very broad perspective, i.e. the society's and the environment's point of view, the hospital can be analyzed in terms of inputs and outputs. So its performance can be improved through a multidisciplinary process of innovation and renovation, under the constraint of specific *boundary conditions.* The definition of a sustainable hospital prototype seems to be difficult and useless, since these structures are deeply connected to the local context where they are situated, both in terms of needs and resources. The evaluation tool thus describes the requirements that must be fulfilled to ensure hospital sustainability, regardless of how they are reached. Moreover, it has definitely shown how the current concept of sustainability is not adequate anymore and requires a different approach, by adding a human component to the traditional economic and financial indications.

Strategies for Improving the Sustainability of a Hospital

In the developed study, the best strategies for existing and new hospitals were identified to create innovative and sustainable healthcare facilities.

Design HVAC Plant to Save Energy

A good design of the HVAC plant is important to save energy. Saving energy means both reducing the environmental impact due to local and dislocated emissions and saving money. Here are provided the essential guidelines concerning the generation systems for an outstanding design.

The first thing is to guarantee the flexibility of the plants; this means that maintenance, renovation and extension processes have to be feasible without radical interventions on the building's structure. This is indispensable to avoid the plants to become obsolete in few years. In this context, the interaction between the plant designer and the building designer is essential.

There are lots of configurations and solutions concerning the design of a good HVAC plant and the right choices depend on the specific situation. However, the choice of the most efficient components must be accompanied by a right regulation system so to allow the components to work most of time at their best performances.

Applying a Lean Approach to Pursue a More Sustainable High Quality Healthcare

Eng. T. Ohno, one of the creators of the Toyota Production System is often quoted for stating that organizations must 'start from need'. In today's world the need for sustainable healthcare is very clear, in terms of *quality and patient's safety, costs, waiting times* and *staff morale* (Graban 2012). On the base of literature findings and interviews with healthcare professionals, it can be argued that a more sustainable kind of healthcare may be achievable; a care that is patient-focused, with less waste, lower costs and better medical outcomes. What has been stated previously describes the essence of a Lean Approach applied to healthcare, according to which processes can be viewed from patients' eyes, seeking to purify them from waste. According to Ohno, wastes can be classified in eight categories as follows: *defects, overproduction, transportation, waiting, inventory, emotion, over processing, talent and human potential* (Capolongo 2006).

In many, if not all cases, examples of these eight categories of waste can easily be found in any healthcare setting. This does not imply that Lean is not focused on improving value-added activities as well. On the contrary, it is this restless elimination of waste that leads to time savings for employees that can in turn devote themselves in activities that are valuable for patients' health. This results in an increased amount of value, being added without requiring for more resources and time.

Material Selection

The selection of the building materials is an important phase for in-design hospitals, where many sustainability achievements can be obtained. However it is characterized by a dual aspect, on one hand it is possible to maximize sustainability, on the other hand is mandatory it to respect some safety and comfort levels for hospital users, since the hospital is a very complex structure, also regarding its necessities in terms of hygiene or safety from fire and earthquakes.

Considering these constraints, to achieve sustainability the designer should focus his attention on some important components of the hospital, which, if correctly studied, can drastically increase the overall sustainability of the project.

In this case the most important elements are substantially the finishes such as: floors, walls, partitions and ceilings. Also furniture is important in the selection phase to foster the sustainability outcome, mainly considering the one for offices, public spaces and hospitalization blocks.

As far as finishes are concerned, many are the realized buildings where designers have selected sustainable materials. Designers have applied many different strategies. A very important one is to select materials with low embodied energy content as wood, bricks and stone.

For what concerns stone, it is important to consider that it is a sustainable material especially if it is available near to the building site. Therefore, when choosing this material, it is important to search for local producers to minimize the transport-related CO_2 emissions.

A further step in the search of sustainable materials can be the use of natural fibers in insulation; commonly used are vegetable and animal ones, as for example kenaf and sheep wool. This kind of solution is very diffused in civil architecture, but not very much used in hospital design. This deficiency in the use of such natural materials for public buildings could be related to the suspicion on some hygiene related issues. This happens although the manufacture processes have been already studied and certified.

Among metals, very often used for windows' frames, it is right to cite the sustainability of aluminum, which is an energy expensive material in its manufacture phase and therefore a CO_2 creator, but it is highly recyclable. Thanks to this property the embodied energy may be distributed on many different life cycles of the material, and it is thus possible to use aluminum which derives from recycling processes.

Waste

Today waste is often recognized as a raw material and a number of developed countries have even started to import it to support their strong recycling industry. In hospitals, waste is a critical environmental health and safety issue which has to be treated with consciousness (Martin and Miller 2005).

Waste manipulation (procedures, transportation routes and related responsibilities) is usually defined in the Waste Management Plan (WMP), a document where exact procedures and responsibilities are listed. WMP should define good waste segregation at the point of generation in hospitals, which is the first and the most essential step in a good waste management. To reduce mixing of waste adequate separation of infectious and general hospital waste, should be ensured and further separation should be realized. All types of waste should be temporary deployed in a protected waste collection-site. Usually, external authorized subjects are involved in further waste transportation and treatment. Special attention should be put on staff training to avoid potential accidents.

HealthCare Without Harm (HCWH) recommends creating hospital site working groups with focus on waste, to develop, monitor and enhance waste reduction programs. In order to ensure the success of such groups, cooperation by experts in all departments and all occupational groups within a hospital is needed. In addition, any waste reduction program requires regular monitoring, to keep constant performance and to be able to set short and long terms goals. Cost and savings of such programs need to be estimated carefully before starting any activities.

Before launching any waste reduction program, staff should be adequately trained in order to change their daily routines.

While choosing products, beside environmental and sanitary facts, another critical aspect to consider should be their potential for reuse and/or recycling. If possible from a hygienic point of view disposable products should be eliminated. Even though reusable products require cleaning and thus consume energy water and disinfectants, the total spending on their purchase and application is lower than in the case of single-use products.

Environmentally Preferable Purchasing (EPP) means assessing the environmental and human health impact of products before they have been bought, choosing the least harmful products/services. One may eliminate products that contain mercury, chlorine compounds, bromine, cadmium, lead and other toxins. EPP encourages a gradual and ongoing process by which a hospital continually refines and expands the scope of its efforts to select healthy, safe and environmentally sound products and services.

It could be concluded that solution for better waste management lies in the challenge of synergizing hospital procurement, improved segregation of nonmedical waste and avoidance of incineration, accompanied by increased awareness and positive attitude from the employees.

Centrality of the Person

Modern science and medicine have already understood that the human body is not a complex 'machine' that needs to be repaired but a person that has to be respected and helped in order to live healthy since *Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity* (World Health Organization 2012).

Therefore every kind of hospital, new or existent (where possible) must strive to be fully focused on the person, becoming a truly social place, a reference point in the community, which does not imply exclusion, but rather inclusion and well-being. This is possible through a concrete involvement policy, both in the therapeutic process and in the design one. Understanding the main needs of hospital users is the first step to build a hospital environment able to answer to a growing demand for listening, humanity and care.

One of the best world examples of a healthcare centre which has its motto *Patient always first* is the Swedish hospital New Karolinska Solna which is still under construction. This particular new project has become a worldwide leading model for social and innovative hospitals. The organization and the design of the project are absolutely user-focused, increasing the protection of the patient and of the staff as much as possible.

Another important feature in a hospital is the quality of the spaces: attention has to be paid to a harmonious environment, which has to be clear, diversified in materials and finishes, able to welcome every type of user (patient, staff, visitor, etc) and to offer different activities and facilities. This can make the users, who are there due to healthy problems or work there every day, feel comfortable in a friendly and safe environment.

Going Beyond

In order to thoroughly test and improve the evaluation system's capabilities, it should be applied in the future to different operative and in-design hospitals, so to verify its performance with a comparative analysis. The system should be tested on operative hospitals built up in different periods, to point out the real applicability of the instrument to buildings characterized by different construction systems (Fig. 5.9).

Moreover, the application of the system testing to a statistically relevant amount of operative Italian hospitals could be useful to define a database of the current situation of the NHS in terms of adopted *technologies, management, resource consumption* and *user satisfaction*. The Ministry of Health could then use the database in order to issue new regulations concerning operative and new hospital structure.

The effectiveness of the emerging solutions proposed should be tested too, through a subsequent evaluation to be carried out after a sufficient transition time from their application, in order to allow the implemented measures to become effective.

The weight proposed for the different levels of the evaluation method could be reviewed by a more heterogeneous focus group, including a representative from each category of users of the hospital. This would enrich the network connecting criteria by also taking into consideration mutual influences. On the basis of these connections, a mathematical system could then be created to define the weight of

Fig. 5.9 The logotype of the SustHealth research work

the evaluating system's different components thus avoiding excessive noise due to personal and non-objective opinions given by the focus group's experts, while also taking into account a more complete range of factors.

Finally, in a large scale perspective for the application of the tool, the European context should be more deeply studied and analyzed, not only in terms of state of the art and best practices, but also looking at the real current scenario, in terms of actual needs, available and required resources and, especially, actual performance.

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