Assessment of indoor environmental comfort in a recently renovated office building in Messina city

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Abstract. In recent decades, the construction industry has made significant progress in promoting sustainable buildings, with a particular emphasis on reducing environmental impact and energy efficiency. However, human well-being and occupant health have become increasingly central themes in this field. Awareness of the fact that the quality of buildings can significantly influence people’s health and psychophysical well-being has grown, leading to the adoption of a new approach in building design and evaluation. The main objective of this work is to explore the foundations for defining a “Healthy Building,” present a measurement model that takes into account various key aspects - thermal comfort, acoustic comfort, biophilia, functional efficiency of the workspace, perception of air quality, lighting quality, light colour and rendering, cleanliness, personal control of systems, privacy, emergency situations, and occupational safety prevention measures, among others - that contribute to the well-being of building occupants, and propose design rules/hypotheses through a case study office building located in the city of Messina. This approach is based on sustainability principles, but it goes beyond, focusing on the comfort, health, and well-being of people living and working in these spaces, examining the various aspects of a “Healthy Building” and how they can be measured and properly certified.

1 Introduction

The Covid-19 emergency has significantly accentuated the attention paid to both the hygienic-sanitary conditions of the environments, in particular the most frequented indoor rooms, and the symptoms attributable to the Sick Building Syndrome – SBS, recognized by the WHO (World Health Organization) in 1986 and considered the pathology associated with staying in “unhealthy” places of industriousness and residence. The syndrome groups together a series of disorders related to those aspects of the microclimate to which people who spend most of their time in “confined” environments are regularly exposed, in this regard this path of research and analysis has been undertaken, to compensate for the insufficient or even lack of attention, information and protection regarding the construction sector for the tertiary sector about the requirements of our work environments: we wanted to understand both how we came to talk about Healthy Buildings and what are the fundamentals that define

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a healthy building; and how we intend to certify the quality of the built and what has been deduced from past experiences. So that future generations, in view of the new action plan adopted by the European Commission, can reach the goal of zero pollution, Green Deal, set for 2050, within healthy buildings.

In the further vulnerability induced by the pandemic situation, the research retraces a synthetic and more recent historical framework on the issue of SBS, outlining the “specifications” of the healthy building, in order to understand how to prevent or possibly solve the problems induced, always keeping in mind that viruses, bacteria, microparticles, allergens and pollutants are all to be taken into consideration, since the presence of a single category already implies signals due to SBS, causing a general state of malaise and symptoms of the nervous type (headache, dizziness, nausea, difficulty concentrating, tiredness, prostration, easy irritability and drowsiness), ocular (dryness, excessive tearing, conjunctivitis, burning, weakness and difficulty focusing), respiratory (coughing, increased nasal secretions, burning, heavy breathing, asthma and shortness of breath) and non-specific hyperactivity (rashes, erythema, itching, alteration of taste and smell). They are much more complex and require reports to the health authorities of some more significant diseases related to infections ( legionella, coronavirus, etc.), some hygienic treatments of patients and the adoption of precise containment measures.

In the last years of the last century, numerous studies were presented [1] that contrasted between “Sick Buildings” and “Healthy Buildings”, some manufacturers of building materials modified the chemical compositions and the rules of good functioning of ventilation systems. In 1999, a study by the Karolinska Institute in Stockholm questioned the term SBS as a syndrome, and in 2006 the Swedish National Board of Health and Welfare discussed in the medical journal Läkartidningen that the term Sick Building Syndrome could no longer be used as a clinical diagnosis [2]; thereafter, it became less and less common to use terms such as Sick Buildings and Sick Building Syndrome in research, but the concept remained and still remains alive in popular culture and is used to designate the series of symptoms related to poor house or work environment engineering.

At the beginning of the 21st century, there was a growing interest in both the health of buildings and the way in which certain materials used to build them can affect the well-being of humans and the environment, encouraging the improvement of transparency regarding hazardous chemicals and the innovation of products that respect the health of individuals and the planet. Many ways/tools/concepts have been developed to determine indicators and performance criteria for healthy and comfortable buildings, focusing in general on the prevention of health and comfort problems; The most important observation of these modes/tools/concepts was that, since the relationships between question and answer in general were incomplete, most of the criteria did not seem to be useful. It was therefore necessary both to conceive a different or at least adapted approach to the assessment of the health and comfort of the occupants in the indoor environment, and to adopt an integrated multidisciplinary vision capable of considering positive and negative stimuli and dealing with people’s “real” needs.

A consequence of this approach has been the take-off of several certifications such as WELL (2014), launched in 2014, one of the first systems to define the parameters with which buildings can improve our lives, focusing on the comfort of the individual; this protocol has been divided into ten categories called Concept: Air, Water, Nutrition, Light, Movement, Thermal Comfort, Sound, Materials, Mind, Community. Or certifications such as LEED (1993), GBC Italia (2009), BREEAM (1990), Fitwel (2016) and others. In 2017, another study on Healthy Buildings was conducted, by Joseph G. Allen and Ari Bernstein of the Harvard T.H. Chan School of Public Health [3], with which many distinct components were identified that can support the well-being of the individual in buildings. The analysis of the previously mentioned studies and also the in-depth analysis of the certification protocols
already in use on a national and international scale have made it possible through this study to examine the comfort and overall quality of indoor environments in historic buildings with office use, trying to develop a definition that is as broad and realistic as possible. The movement for “green” construction has already addressed issues such as energy, waste and water, we will see a new movement, in this regard, for “healthy” construction, placed at the centre of the research work and which focuses on the most important resource: users. In a long-term perspective, the research work carried out should provide an innovative contribution to the evaluation of existing buildings, with reference to the fundamentals to make a comfortable and safe work environment, therefore in turn a healthy building, and to certifications, offering an innovative post-occupancy evaluation designed and tested (case study located in the Messina area, it is Building E which is part of the central complex of the University of Messina) to be used specifically in the evaluation of historic buildings.

2 Materials and Methodology: The Foundations for a Healthy Building

The protection of health and the possibility of intervening based on certain parameters pass through the elaboration of the values that define the Healthy Building, which can be binding or recommendation. It is clear, however, that these are reference values, valid as they are supported by research if new acquisitions do not affect their legitimacy. It is therefore a question of setting rules, working hypotheses, which must be continuously revised as knowledge in the specific sector progresses. The fundamental problem is to establish values that guarantee the protection of health, but which are also manageable in situations that are sometimes highly compromised.

All this with the aim of constructing/restoring/regenerating buildings in a sustainable way from start to finish, prioritizing our planet, the health and well-being of future occupants [4]. The current definition of health is the basis of a collective vision of medicine, which loses the character of an isolated discipline, but becomes closely interconnected with social, cultural, environmental, and economic factors. The desire to abandon the concept of health as the absence of disease would lead many disciplines to deal not so much with the aim of eradicating diseases, but with preventing them through the care of the person and living spaces.

The individual has been considered beyond his purely biological condition, as an entity in balance between himself, his body, and the surrounding environment. On the one hand, therefore, there is a clear reference in considering the person as a mind/body whole. On the other hand, health is considered from the point of view of the person himself: well-being must therefore be understood as intricately linked to a personal and indisputable expectation about one’s physical and mental condition, which depends on the idea that an individual has of himself. We consider ourselves healthy if we feel good based on that standard which for us is the ideal condition. Deviations from this parameter of personal well-being can be due to both individual problems, both physical and psychological, as well as environmental: to restore the health of the individual, the treatment must therefore consider all these points. Pursuing such a goal involves the need not to limit oneself to curing a disease, but means going beyond, towards complete well-being. This, if on the one hand has led to greater defence for individuals, on the other hand has caused a greater medicalization of society.

To foster greater development and greater attention to this continuous evolution, the Healthy Buildings movement promotes a new comprehensive approach that emphasizes and deepens a number of factors and systems, characterizing and encouraging interactions between various fields of expertise. To this end, the Harvard T.H. Chan School of Public Health [5] conducted a study on Healthy Buildings, with the aim of drawing up some key points – or fundamentals – that determine and represent the state of health in a building [6].
2.1 Air quality

The foundation called “air quality” aims to ensure high levels of quality performance for indoor air throughout the life of a building; this is possible through different strategies that include: the elimination or reduction of polluting sources, the design of active and passive buildings, operational strategies and interventions on human behaviour. People spend about 90% of their time in enclosed spaces [7]: homes, offices, schools, or other destinations. During this time, inhalation exposure to indoor air pollutants can lead to a variety of short- and long-term adverse health and wellness outcomes, which can vary in severity. Less severe symptoms of exposure may include headaches, dry throat, eye irritation, runny nose, while more severe manifestations may include asthma attacks, bacterial infection (e.g., legionella), and carbon monoxide poisoning [8] [9].

2.2 Ventilation

The foundation of ventilation allows the recirculation and exchange of air in closed environments: fresh air is introduced from the outside through mechanical and/or natural means in order to dilute the pollutants generated by man and by products or materials present inside. It has been widely expressed that poorly ventilated spaces contribute to symptoms such as headaches, fatigue, dizziness, nausea, coughing, sneezing, shortness of breath and irritation of the eyes, nose, throat and skin. Poor ventilation is also linked to increased employee absence rates from workplaces, higher operating costs for businesses, and decreased student productivity [10] [11]. A study conducted in the United States reported that sick leave attributable to insufficient fresh air supply in buildings is estimated to be 35% of total absenteeism [12]. Therefore, the economic costs of SBS in poorly ventilated buildings are significant and far outweigh the energy-related cost savings [13] [14]. To keep healthy indoor environments and acceptable air quality for building users, sufficient ventilation must be provided [15] [16]. In addition to proper HVAC (Heating, Ventilation, and Air Conditioning) system design, mechanical ventilation designers must perform regular system maintenance, as inadequate maintenance is associated with reduced ventilation performance and deterioration in indoor air quality, as well as thermal conditions [17].

2.3 Humidity

One of the main priorities in the design and operation of buildings is humidity control. There is no bigger problem that a building faces than damage caused by water in liquid or steam form. The task of controlling water and humidity dominates our design and construction: from the foundations to the roof, from the basement to the façade, from the plant pipes in general to the rooms most exposed to the risk of humidity due to the intended use. The reason we worry about moisture or water ingress is that it involves the potential for mold growth. Three conditions must be present for mold to grow: humidity, temperature, and nutrient source; For example, in buildings where there is water infiltration at intervals with sudden but constant temperature changes, plasterboard surfaces and carpets that function as a source of nutrients, there is an ideal environment for humidity. Mold is an inherent health problem because it can cause allergic reactions or can be irritating: as an allergen, mold has been shown to be a trigger and promoter of asthma, as it causes upper respiratory symptoms such as coughing and wheezing; As an irritant, it can act on the mucous membranes of our eyes, nose and throat, and in some cases even headaches. In extreme cases, mold can also erode or damage the underlying material, such as wood, causing irreparable structural damage, but even the mere formation of condensation can compromise some essential performance, such as those related to thermal insulation, especially in porous materials.
2.4 Lighting quality

Light has been the subject of study in various disciplines and in the field of architecture it has been attributed great artistic, symbolic and design value several times. Lighting technology is the discipline that studies the lighting of indoor and outdoor spaces and requires interdisciplinary skills related to the nature of the human eye, electrical engineering, the world of plant engineering and the principles of architectural design. The goal of a lighting project is to offer a condition of comfort so that we can carry out the activities we are called upon to perform in a given place in the best possible way, where the balance between natural and artificial light is the best possible. Studies carried out over time have shown that the effects of light on humans are not limited to a purely visual issue, but strongly affect the cognitive functions of each individual, their psychological condition and above all their biological rhythm (circadian rhythm); An example of this are the studies conducted by the three geneticists, Jeffrey C. Hall, Michael Rosbash and Michael W. Young (Nobel Prize in Physiology and Medicine in 2017), who were able to “peek” into our biological clock so as to clarify its mechanisms: their discoveries explain how plants, animals and humans adapt their biological rhythm so that it is synchronized with the revolutions of the Earth [18] [19].

2.5 Thermo-hygrometric quality

The factors that decide the thermo-hygrometric environment in a confined space are mainly: the thermal and vapour permeability characteristics of the boundary elements (the building envelope), the heat and steam sources present inside, the external climate, the characteristics of the air conditioning system. The final data to be evaluated is the degree of well-being perceived by the occupants in the space considered, i.e. the degree of thermal comfort. The useful tool for this purpose is the theoretical principles and measurement methods for predicting the thermal sensation perceived by people. The thermo-hygrometric environment is described by appropriate physical quantities; Obviously, speaking of perceptual “sensation”, activity and clothing also take on value.

2.6 Acoustic quality

Acoustic insulation is the set of measures taken to reduce the transmission of energy from the sources that produce it to the places that need to be protected. Therefore, the purpose of sound insulation is to protect humans from noise by attenuating or eliminating their perception through the dissipation of sound energy. For several years, noise has been considered one of the main sources of pollution: consequently, man needs to protect himself from sounds and noises. Here are just a few examples of noise sources that we deal with on a daily basis: noise from outside (road, rail, air, naval traffic; industrial or craft activities located in positions not far enough from the built-up area); noises coming from inside (hi-fi, technological, heating, ventilation systems, voices and various activities in the same building unit or in other contiguous ones; impact noises generated by falling objects on the floors, noise of shoe heels). The performance capacity in relation to sound insulation indicates the ability of the building envelope, as well as of the vertical and horizontal internal partitions, to ensure an adequate level of acoustic comfort in the living space in terms of sufficient attenuation of external noise and the absence of “induced” noise in the same envelope that is difficult to tolerate.
2.7 Water quality

The 2030 Agenda consists of 17 Sustainable Development Goals (SDGs) to be achieved by 2030, which in turn are divided into 169 Targets and over 230 indicators, for sustainable development worldwide. The objectives, interconnected and indivisible, have been developed according to the three dimensions of sustainable development: economic, social and environmental. The topic of water is mainly addressed in Goal 6: “Ensure the availability and sustainable management of water and sanitation for all”. Water management is characterized by a particular complexity due to the involvement of numerous stakeholders – service managers, government authorities at different levels as well as the supply chain of the construction sector – and the stratification of levels of competence and authority in the field. In fact, if water services are regulated at EU and national level, the management on the territory is instead the responsibility of Local Authorities and private companies, as well as the determination of tariffs and quality standards of the service fall under the responsibility of the municipalities. Consequently, in order to pursue the objectives in this area, an integrated approach is needed that involves the various stakeholders in long- and medium-term planning, research and experimentation activities [20].

2.8 Dust and parasites

Amuchina, bleach, alcohol and disinfectants based on these, report in their use sheet, with reference to the environmental effects, statements such as: polluting water, toxic for aquatic organisms and for the marine ecosystem, persistent. And as for the health effects: toxic or irritating to the respiratory tract, it can cause burns or injury to the cornea, corrosive (bleach). Thus, these products, with run-off or thrown directly into the drains, enter the water cycle, having a devastating effect first of all on the marine ecosystem, but also on the microorganisms of the food chain. They can also be toxic if breathed in or in contact with the skin, but they can also cause accidental poisoning, especially in children. It does not seem just a coincidence, in fact, that in conjunction with the outbreak of the Covid-19 epidemic, the Centers for Disease Control and Prevention reported a 20% increase compared to the same period in 2019, and Italy is no exception.

2.9 Safety & Security

Closely linked to cultural and social aspects that unite areas and entire countries, taking on different meanings and manifestations, the sense of protection and security, intangible but written in human genetics, is one of the most important elements that help maintain health. Its constant absence (or even just the feeling that it is missing) can lead to the chronic rise in stress levels with influences on the functioning of the immune system, the state of general inflammation, blood pressure levels and the cardiovascular system, as well as depression and consequences in social behaviours. Buildings can also play a key role thanks to the influence that certain measures, such as railings and the presence of security systems, have on the reduction of fear. With Legislative Decree No. 81 of 2008, updated in July 2023, attention was focused on the risk of work-related stress, expressly recalling the 2004 European Agreement, to define its value and the policies to be adopted to prevent it, which identifies it with a “state that is accompanied by physical, psychological or social malaise and dysfunction and that results from the fact that people do not feel able to cope adequately with the demands or to the expectations of them” (Legislative Decree no. 81 of 2008). Stress is not a disease, but a prolonged situation of tension can reduce efficiency at work and can lead to poor health, becoming a safety risk, as it decreases the perception of risk and alters behavioural processes.
The analysis of the study conducted by Allen & Macomber, 2020 on Healthy Buildings and the in-depth analysis of the certifications in use and the different survey systems, post-employment assessments, increasingly used in the engineering field, have revealed the lack of attention to some topics, such as mental health, nutrition and movement, considered today, in the society in which we live, Issues of a certain depth, especially to be considered central in the field of psycho-physical well-being. In this regard, it was considered appropriate to suggest the introduction of 3 new foundations, which take the name of “mental health, nutrition, fitness”, considered an innovative part of the research work, to be used through the appropriate certifications as an integral and complementary part to make a building healthy.

2.10 Mental Health

Mental health is a critical component of human health at all stages of existence and is vital to the physical and social well-being of all individuals, communities, and societies. It is not just about avoiding any deficiency of a mental health condition, but rather about trying to ensure a state of well-being in which individuals are able to reach their full potential, cope with life’s normal stressors, work productively, and contribute to their communities [21].

2.11 Nutrition

Our eating patterns are influenced by a complex combination of personal, cultural, and environmental factors, including the buildings in which we reside and the communities in which we spend most of our time and consume most of our meals. The way our food environments are designed and managed, as well as the availability and access to food and beverages, has the potential to support healthy diets and improve human health while keeping the health of the planet in mind. In fact, research shows that individual change is more likely to occur when environmental conditions and influences are aligned to support individuals’ behaviours [22].

2.12 Fitness

Movement is closely connected to all aspects of daily life. Physical activity encompasses a wide range of domains of dynamism, including work, transport, domestic and leisure activities. Our understanding of the relationship between physical activity and health continues to evolve, we know that all movements are important for health and that physical well-being can be accumulated or compromised throughout the day in a variety of ways. Therefore, it is crucial that our buildings, our socio-cultural environments and our communities consider movement as a vital part of the human condition and as a key tool for health promotion itself.

3 APPLICATIONS AND RESULTS OF THE CASE STUDY

3.1 Building E of the University of Messina - Case Study

For the selection of the case study in the context of public buildings owned by the University of Messina, several characteristics that the building had to possess were considered:

- historicity, be over 70 years of age;
- intended use, have an office environment inside;
- state of conservation, have undergone recent restoration;
• accessibility, having the opportunity to carry out various inspections during restoration work;
• type and number of users, be a significant sample of workers of different genders and ages between 40 and 60 years old.

Several buildings in the Messina area were analysed and, in the end, only one fully met, at the time of the beginning of the research, all the requirements. The building that fully met the above requirements of the University of Messina was selected.

An analysis of the drawings found in the archives of the Civil Engineers of Messina (folders nos. 87-88-89-152-156) shows that the building in question, whose name is “Building E”, originally intended for the Institute of Zoology and Comparative Anatomy and Physiology, was conceived on three levels, two above ground and a cellar, covering a total area of 528 m², with sides of 30.00 m by 17.60 m and a height of 11.40 m. The east and west elevations have similar characteristics with five openings on the lower floor while on the upper floor there are three large openings with balconies on the chest and, laterally, two mullioned windows. The other two façades (north and south) are characterized by seven large openings on the lower floor of which, on the north elevation, the central one is the main entrance and seven on the upper floor Figure 1. The direct survey operations, carried out with traditional methodology (measuring tape, metric wheel, laser ruler, metric rods, plumb line, levels, etc.), have made it possible to take note of the new internal distribution of the building as a result of the changes made in the mid-90s to adapt the building to new administrative needs: in place of the original institutes there will be space for offices and secretariats and, specifically: the Salary Organizational Unit, the Talent Management and Training Technical Coordination Unit and the General Affairs Administrative Department. The main internal partitions have been maintained, but the rooms that in the past housed the exhibition spaces have been divided to obtain the various offices. The large vestibules no longer exist, as they have been replaced by small rooms to be used as a printing centre or to implement the number of toilets; The central part on the ground floor serves as a warehouse, while on the first floor it serves as a meeting room and archive. The ceilings of all the studios and classrooms have maintained the original height of 4.80 m on the ground floor and 4.60 m on the first floor; This feature, together with the large size of the windows, resulted in a greater perception of the interior space than it actually was in reality. The location of the building also allowed for excellent natural lighting at all hours of the day and ideal natural ventilation inside, since in the surrounding area there were only the green spaces of the University and the two streets (Via Verdi and Via G. Venezian) Figure 2. The presence of small trees did not represent an obstacle to the passage of air, which was therefore continuous and favourable, regardless of the direction of the wind. Today, unfortunately, the building is surrounded to the east by the new building (twice as high as the building under consideration), which houses the Department of Economics, while to the north and west, the tree-lined system along the two streets has become larger and denser; Both of these factors compromised the correct assessment made during the execution of the original project with regard to the problem of ventilation and natural lighting.

Recently, the redevelopment of the building has been completed, affected by the effects of the deterioration of the plaster on the elevations, decorative friezes and cornices; The problems related to the degradation, by carbonation, of the cement conglomerates and the detachment of the concrete roof due to oxidation of the underlying reinforcements were also solved. The project also included the waterproofing of the roof terrace which did not guarantee the necessary protection against rainwater infiltration, the replacement of all the
anodized aluminium fixtures with wooden ones and the positioning of parapets on the roof level.

Fig. 1. Above: General plan on a scale of 1:200, Below: Ground floor and first floor plans on a scale of 1:100 of the building E according to the original project (Archive of the Civil Engineering of Messina).
3.2 Analysis of users' environmental well-being

In new buildings it is easier to design with comfort in mind, since all the parameters that could affect the environment can already be taken into account during the design phase, while in slightly outdated buildings a check of the floor and the state of the places before the intervention is essential. Just as it is even more so to deepen the pre-intervention study with a possible interview with the residents; since the changes necessary for the overall
improvement of the offices may concern various unknowns (systems, windows, materials, internal arrangements, temperatures, humidity, incorrect lighting, etc.), which can be suitably improved with total or partial additions and/or replacements. In this regard, a satisfaction questionnaire has been designed to have a broader view of the state of comfort or discomfort of users. In this research, the questionnaire was distributed thanks to the help and collaboration of the Analysis and Reporting Organizational Unit, precisely by the Customer Satisfaction Commission of the University of Messina. The method of administration was closed access anonymously on the Limesurvey platform, through an e-mail invitation containing the link with the token to participate in the survey, all forwarded exclusively to the target audience. The questionnaire consists of 5 sections: the first with general questions, the second with technical information, the third based on the MM040 questionnaire used in the Scandinavian countries [23], the fourth along the lines of the SF-12 health questionnaire and the fifth section with questions related to possible sleep disorders and circadian rhythm.

3.3 Data processing, choice and application of certification

Overall, evaluating all the answers to the questionnaire and the various percentages of discomfort, it emerged that the redevelopment interventions on the building have improved various technical aspects of the structure (change of fixtures, terrace renovation, addition of parapets and renovation of elevations) important for the operation of the entire “building system”, but no plant or comfort works have been carried out of the user. Overall, users are not fully satisfied, as half of the respondents reported a variety of discomforts, which are likely (as inferred from sections 4 and 5) to cause both mental health problems and biological rhythm disturbances Figure 3-4.

Among all the various certifications viewed, the only one at national level that deals with historic buildings (understood as a building artifact that constitutes material testimony with civilizational value) is GBC Italia, which was selected for the application. The analysis of the design parameters was carried out through the GBC Historic Building manual, the GBC Italia protocol certification regulation and the Checklist for the restoration and certification of historic buildings, all present on the GBC Italia website, in order to: develop the “Identity Card of the historic building”, considered a fundamental and essential phase to comply with the first requirement, mandatory, of the “Historical Value” category, with the aim of preserving and protecting the historic architecture subject to intervention. The various categories and scores assigned by the protocol are described and reported below, so as to establish what level of certification the building in question would have achieved if the building had been subjected to verification before the restoration intervention, taking into account instead the 9 classic fundamentals for a healthy building. In this case, it must be borne in mind that the final score, however, does not consider the 3 new foundations proposed (nutrition, mental health, fitness), since they are the innovation of the present research and are not contemplated in the categories of certification; therefore, it is possible to highlight that with their addition, the value of the certification to be applied would have increased further. By giving these 3 new foundations a “reward” value, for which it is still necessary to establish any scores, the certification would still have a value with important weight, but a more complete technical character due to the possible prizes in the 3 fundamentals.

In the “Historical value” section, a score of 12/20 was assigned, and significant importance was given to the inclusion of an expert in architectural heritage in the team. As far as the “Sustainability of the site” is concerned, a score of 8/13 was assigned. In the “Water Management” category, a score of 6/8 was obtained and, in addition to reducing consumption, it was decided to account for it through the installation of special meters.
In the “Energy and Atmosphere” category, a score of 15/29 was assigned, with regards: on the optimization of energy performance; on renewable energy, proposing a photovoltaic system with monocrystalline silicon modules with a single power of 0.5 kWp, 2094x1134x35 mm, consisting of 30 modules inclined at 31° and oriented towards the south, which allow to generate a total power of 15 kWp (Sun-Earth, n.d.; Tool for Grid-Connected PV Efficiency, n.d.) [24], [25]; advanced commissioning of energy systems; advanced refrigerant fluid management and testing measures. For “Materials and Resources” a score of 6/14 was also given in this case. In the “Indoor Environmental Quality” category, on the other hand, the score rose to 13/16, and all the items concerning the fundamentals of Healthy Buildings obtained the maximum score so as to ensure high indoor comfort.

For example, as far as indoor air quality is concerned, an air conditioning system with primary air and fan coils is proposed, equipped with spare parts for the healthiness of the environments. For ventilation, on the other hand, systems with high filtering capacity have been designed so as to allow more effective air circulation. In the criteria concerning the use of “low-emission materials” (credits 4.1, 4.2, 4.3 and 4.4) 2 out of 4 points were assigned because the use of building materials (adhesives, sealants, cementitious materials, finishes, paints, coatings and paints) chosen by avoiding the use of chemicals that can put significant quantities of odorless but at the same time harmful airborne substances such as VOCs was proposed. The maximum score was not obtained because there was no restoration of the flooring or wooden material. During the restoration activities, a plan for indoor air quality is also proposed, paying particular attention to sources of internal pollution due to the work process, so as to ensure the health of the installers, the internal cleanliness of the construction site and the protection of materials from humidity and any contamination. The “Innovation in Design” category remains 3/6. Finally, the last point, “Regional Priority”, gets 4 points, since in the previous categories it recovers points. Overall, the building would have obtained
a gold certification with a score of 67/110, where 19/24 concerns only the fundamentals of Healthy Buildings.

Fig. 4. Results related to which factors have the greatest impact on comfort.

4 CONCLUSIONS

Taking into account that surveys through the use of occupant surveys continue to be an effective method to evaluate the performance of buildings and indoor environments, the work also focused on the design and validation of the toolbox, in order to demonstrate the feasibility of applying it in a post-occupancy survey based on the fundamentals for a Healthy Building and to test the effectiveness on possible future certification. In particular, the indications obtained from the questionnaires were significant in defining and ordering improvement actions in buildings, in providing important feedback to builders and designers, but also to the occupants themselves, and to provide guidelines and indications to improve the quality of indoor comfort and psycho-physical well-being. The results show that there is greater dissatisfaction among occupants with regard to: maintenance, cleanliness, acoustic quality, thermo-hygrometric quality and lighting quality. The sections of the survey relating to topics that are little known in the evaluation of buildings but fundamental in certification, have given the opportunity to identify a series of important feedback to understand the habits, trends, expectations and behaviours of occupants in relation to concepts such as movement, mental health, water, nutrition, interaction with nature and with others.

The results obtained from the survey made it possible to identify certain problems from the point of view of the building-plant system, where some of which can be solved through targeted actions: for example, correcting the response systems of thermostats in rooms, regulating air changes in mechanical ventilation systems and improving lighting quality. The results obtained from the surveys have also made it possible to identify a series of consequences from the point of view of functional distribution of the furnishings, considered especially important for the development of a more conscious design.

Specifically, to achieve the desired standards, meeting spaces (relaxation areas, refreshment areas, etc.) have been proposed to ensure moments of break from work, improvements in the arrangement of furnishings so as to encourage the vision of an outdoor environment, with consequences in the field of biophilia and design. Finally, an attempt was made to highlight how essential it is to use sustainable materials that can improve acoustic quality, thermo-hygrometric quality, and air quality.
Looking to the future, where issues such as comfort and well-being will become increasingly common, post-occupancy surveys in public buildings (offices, schools, libraries, etc.), but possibly also residential buildings, have great potential and should become more flexible and decisive in assessing the effectiveness of environmental fundamentals and certifications in the field of well-being.

According to the results obtained in this work, a possible direction to follow, for future research developments, should be: think about the way in which the certifications and post-employment evaluations of users can be, in addition to being unified in a singular procedural process, defined as necessary and essential in the pre-intervention phases. In the graph below, the results of the survey on the importance, according to users, of “fundamentals” in environments have been schematized.

References


