

Review



Resilient Built Environment: Critical Review of the Strategies Released by the Sustainability Rating Systems in Response to the COVID-19 Pandemic

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Abstract: Since the COVID-19 outbreak, buildings have been viewed as a facilitator of disease spread, where the three main transmission routes (contact, droplets, aerosols) are more likely to happen. However, with proper policies and measures, buildings can be better prepared for re-occupancy and beyond. This study reviews the strategies developed by several Sustainability Rating Systems (SRS, namely WELL, Fitwel and LEED) to respond to any infectious disease and ensure that building occupants protect and maintain their health. The best practices, that are similar between each SRS, highlight that the overall sustainability of the spaces increases if they are resilient. Results indicate that SRS promote a weak sustainability approach since they accept that economic development can reduce natural capitals. SRS are also characterized by an aggregated level of assessment of different criteria that does not allow to map different choices. However, the decomposition of the concept of sustainability in its three bottom lines (i.e., environmental, social and economic) shows that preventive strategies are likely to be systematically adopted as the state-of-the-art. Finally, even if the latest research points out the airborne transmission as the major infection route, the SRS lack analytical measures to address issues such as social distancing.

Keywords: SARS-CoV-2; COVID-19; respiratory disease transmission; indoor environmental quality; sustainability rating systems; green buildings; healthy buildings; LEED; WELL; Fitwel

1. Introduction

Coronaviruses (CoV) are a family of positive-sense single-stranded RNA respiratory viruses, meaning that they have ribonucleic acid as genetic material [1]. Their name comes from the crown-shaped tips present on their surface, and they cause several human diseases, from influenza to Ebola [2].

At the end of 2019, a new type of disease (later named as coronavirus disease 2019, or COVID-19) broke out in Wuhan, the capital of Hubei Province in China [3–5]. Doctors discovered that it was caused by a new strain of the coronavirus family, SARS-CoV-2 [6,7]. It belongs to the same family as SARS-CoV-1, responsible for the severe acute respiratory syndrome (SARS) epidemic in June 2003 [8], and MERS-CoV, the Middle East respiratory syndrome of June 2012 [9].

The World Health Organization (WHO, Geneva, Switzerland) declared the infectious disease an epidemic during its initial outbreak in Wuhan, a pandemic on 11 March 2020 once COVID-19 had spread all over the world without control and, finally, an endemic infection that may remain in our communities [10].

When it comes to epidemiology, the parameter R is used to measure the spread of infective diseases between the population. If R is two, two infected people will, on average, infect four others, who will infect eight others, and so on [11]. The spread of an infection is typically considered under control when R is lower than 1 [10]. SARS-CoV-2 has a basic



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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). reproductive rate (R₀) of 2.5 (range 1.8–3.6), compared to 2.0–3.0 estimated for SARS-CoV-1 and 0.9 estimated for MERS-CoV [12].

MERS-CoV is the most lethal coronavirus, since it often progresses to severe pneumonia with a mortality rate higher than 30%. Similarly, SARS-CoV-1 causes fever, chills and body aches, and often progresses to pneumonia, with a mortality rate of about 10%. SARS-CoV-2, which shows the lower mortality rate (about 2.3%) [13], produces infections in people that can be totally asymptomatic or that can present flu-like symptoms such as fever, cough and breathing difficulties [14]. The most severe symptomatology is more frequent in elderly subjects, in people with concomitant pathologies [15], or in young subjects with a weak immune system (i.e., undergoing acute or chronic immunosuppressive therapy) [16]. Symptomatology is also shown in subjects with a decreased immune defense due to an excessive workload [17], or those who work night shifts with irregularities of the normal circadian sleep–wake rhythm [18]. Patients that develop pneumonia, a severe condition in which the lungs become inflamed and fill with pus [13], can ultimately die due to multiple organ failure [7].

Even if the reproductive rate and the fatality rate of SARS-CoV-2 are different from its predecessors, the modality of transmission is comparable to the epidemics caused by other coronaviruses. The virus enters the body through access routes such as the oral cavity, the nasal cavity, the eyes and other mucous membranes [19], and as shown in Figure 1, three main transmission routes have been identified [20]:

- 1. Contact.
- 2. Droplets.
- 3. Aerosols.



Figure 1. The three primary routes for infectious transmission during social interaction [21,22].

Contact can take place directly with infected people or indirectly by depositing droplets containing the virus on any person (handshake, greeting, hug) or surface (fomite) [23]. Droplets are generated during speaking, coughing and sneezing both by symptomatic patients and asymptomatic people [20]. The risk of airborne cross-infection is defined as the proportion of air mass exhaled by the infected person that is then inhaled by the exposed person [24]. Face-to-face and conversational exposure transmission are the most typical short-range airborne routes [25].

Aerosols are airborne microparticles with a diameter smaller than 5 μ m, which are transported by the flow of the air current, even at a considerable distance (long-range) [19].

The inhalation of aerosols containing pathogens is also possible because SARS-CoV-2 remains practicable in aerosols for hours [26].

It is difficult to quantitatively compare the relative contribution of airborne transmission with other transmission modes (i.e., contact and droplets). In fact, infection may occur via all routes to different degrees depending on the specific exposure circumstances. Therefore, effective infection control necessitates protection against all exposure pathways. If medical and biological factors are considered (e.g., infectious dose) along with the engineering factors, the comparison becomes even more sophisticated [27]. However, several studies provide strong evidence for indoor airborne transmission of viruses, particularly in crowded and poorly ventilated environments [28,29]. Infectious pandemics that happened in the past forced the development of new strategies in the built environment as a contribution towards preventing the spread of infections. These measures helped not only to reduce the risk of disease transmission (or even prevent it), but also to increase the resilience of the built environment [30].

BREEAM defines resilience as "the capacity of built assets to endure acute shocks and chronic stresses while successfully adapting to long-term changes". Resilience is seen as "an integral part of sustainability that creates a better future for the environment and society" [31].

Some authors agree with the fact that pandemics and extreme events resulting from climate change are warnings from the planet that the limits may have been reached and that a more structural approach should be adopted, combining environmental concerns with the focus on sustainability [30,32].

The greatest historical pandemics have leveraged changes designed to introduce protective measures into buildings that are summarized in Table 1. In fact, the built environment not only increases or decreases exposure conditions (i.e., lack of water or poor air ventilation), but it can also create diseases (i.e., HVAC, indoor plumbing and hot water systems can create new conditions for the spread of Legionnaire's disease) [30,33].

Epidemiological Period Measures on the Built Environment Disease Aqueducts, water and Infectious diseases 2nd century sanitation systems [34]. Black Death/ Larger public spaces with 14th century **Bubonic** Plague more organized layouts [35]. Sanitation of sewage systems to stop Cholera 19th century fecal-oral transmission route [36,37]. Modern minimal design with terraces, balconies Tuberculosis/ 19th century and flat roofs to capture sunlight and air [38,39] and reject White Plague dust, pollution and diseases [40]. Spanish Flu 20th century Social distancing and gauze masks [41,42]. Taking people's temperatures [8] and SARS-CoV-1 21st century

Table 1. Historical infectious diseases and their implications for the built environment [30].

2. Aim and Purpose

The introduction highlights the epidemiology and symptomatology of SARS-CoV-2, whose foundations come from sources collected between 2020 and early 2021, as shown in the Reference Section. Due to the hot topic, some values and parameters may vary in the future, but the general concepts are consolidated, given the experience with previous infectious diseases. The introduction also focuses on the transmission routes of the virus and the behavior of droplets and aerosols in indoor spaces.

improved ventilation and drainage systems [43].

The U.S. Centers for Disease Control (CDC) represents a hierarchy of infection control from the most to the least effective [44]:

Elimination: physical removal of the hazard.

- Substitution: replace the hazard.
- Engineering controls: isolate people from the hazard.
- Administrative controls: change the way people work.
- PPE: protect the workers with personal protective equipment [44].

With such a background, the aim of this study is to review the strategies specifically developed in response to the COVD-19 pandemic and valid in case of any infectious disease. They are meant to reduce exposures to occupational hazards inside the regularly occupied indoor environment, where cross-infection is more likely to happen. If spaces are resilient, their overall sustainability increases. For this reason, this study aims to critically review the strategies developed within the most recognized Sustainability Rating Systems (SRS), which can be defined as the process of identifying, measuring and evaluating the potential impacts of alternatives for sustainability. Even though they are characterized by some limitations, SRS are globally recognized tools to assess building sustainability due to their solidity and applicability [45].

The manuscript aims to clarify two aspects that are not critically reviewed in the state-of-the-art:

- 1. Any lack within the strategies developed by the Sustainability Rating Systems specifically to minimize the transmission of infectious diseases.
- 2. The level of sustainability of the above-mentioned strategies addressed in response to the COVID-19 pandemic.

Sustainability Rating Systems are constantly updated in order to meet the industry development and achieve a reasonable balance among the three pillars or triple bottom line of sustainability, namely, environmental, social and economic sustainability [46], as shown in Figure 2.



Figure 2. The three pillars of sustainability.

Even though this represents a simplification of a complex concept such as sustainability, the decomposition allows to measure the level of sustainability of each strategy in a more methodic and accurate way. In particular, this study analyzes the degree of sustainability of the measures addressed by the SRS in response to the COVD-19 pandemic.

The last decades of the SRS have been characterized by a slight decrease in the weight of the environmental category, an increase in the weight of the social category and a minor rise in the weight of the economic category. In particular, within the social category, wellbeing has the highest proportion, with physical comfort showing the fastest growth [46].

Among the SRS, "Green Building Rating Systems" (GBRS) have the environmental sustainability as their primary motivator, while "Healthy Building Rating Systems" (HBRS) are mainly focused on occupant health and wellness. While the first ones have been established for almost 30 years, the latter are more recent. Developed upon the health-related credits of GBRS, HBRS leverage academic research to prescribe measures to create workspaces that reduce absenteeism and enable wellness and productivity of their occupants through prescriptive limitations as well as performance-based credits [47]. Lately, GBRS have been incorporating more and more requirements for occupant health and wellness, showing the increasing interest in this area by both building designers and end-users. Besides, the Real Estate sector has also demonstrated an increased interest in this area, as evidenced by the amount of assets registered under the HBRS [47].

The consistent spread of SRS across different regions and asset classes can be found in their nature: they are intuitive and practical tools useful to design a built environment resilient to infectious diseases. Most of the evidence-based measures within them, spanning building design and operations, as well as company policies and behavioral changes, provide a practical framework for buildings and occupants responding to the pandemic and preparing for a safer and healthier future. For this reason, the aim of this work is to review applicable strategies that reflect how stakeholders can approach prevention and preparedness, resilience and recovery in response to COVID-19 or any other respiratory diseases [48].

In the literature, there are several studies that explore the evolution of Sustainability Rating Systems and their multi-criterion nature based on indicators and benchmarks [49]. However, no papers in scientific journals investigate the evidence-based best practices developed to mitigate the spread of infectious diseases and their level of sustainability.

3. Methodology

Among the dozens of Sustainability Rating Systems available all across the globe, this study assesses in detail WELL, Fitwel and LEED. In fact, they have been the only ones to officially publish ad-hoc strategies in response to the COVID-19 pandemic, even though other Ratings have also highlighted the importance of transmission control inside the built environment [50,51].

3.1. Publications

The first was the WELL Building Standard, managed and administered by the International WELL Building Institute (IWBI), whose Task Force released the WELL Health-Safety Rating for Facility Operations and Management in June 2020 to help guide stakeholders to evidence-based best practices for navigating through the crisis, as well as for long-term preparedness on any other critical health and safety issues [52].

WELL was immediately followed by LEED, managed and administered by the U.S. Green Building Council (USGBC), that released six LEED pilot credits in June 2020 to help building teams provide healthy spaces, and to assist with re-entry [53].

Finally, Fitwel, originally created by the U.S. Centers for Disease Control (CDC) and Prevention and U.S. General Services Administration, in September 2020 released the Fitwel Viral Response module in direct response to industry demand surrounding the COVID-19 pandemic [54].

3.2. Scope of Application

The SRS considered in the review share the following nature:

- Internationally applicable (not country-specific).
- Voluntary (standards and codes are excluded).
- Focused on buildings in operation with a defined fit-out.
- Referred to mechanical ventilated workspaces.

They are all internationally applicable because they are based on the belief that the occupants of buildings based, for instance, in America, Asia or Europe, have similar needs, even if the assets have different boundary conditions.

They are voluntary; therefore, the strategies are more demanding than the minimum requirements included in a typical local standard or code.

They refer to buildings in use because most of the strategies are operations policies and maintenance procedures of already occupied spaces.

They consider office spaces because they are commonly recognized as the main vectors for the transmission of infectious diseases [30,55].

This is particularly important considering that workplaces must face a post-pandemic future, with a hybrid virtual model that combines remote work with time in the office, according to a survey from McKynsey & Company [56]. In fact, while productivity increased during the pandemic, many employees reported feeling anxious and burned out and a provision of a safe workplace seems essential.

Assets that do not reflect the four characteristics (i.e., buildings under construction or in a core and shell state, residential buildings, etc.) should also follow the recommended strategies from an early stage to enhance an integrated design process [57–60].

3.3. Degree of Sustainability

This study aims to measure the degree of sustainability of the strategies addressed by the Sustainability Rating Systems to minimize the transmission of infectious diseases. To do so, the concept of sustainability is decomposed in its three bottom lines, namely, environmental, social and economic. Even though this represents a simplification, the process allows to determine the level of sustainability of each strategy in the most accurate way.

Since the measures are intended to enhance the human health and safety, the social component is the main target of every strategy. However, the environmental and economic components vary consistently. For instance, if a strategy has high levels of environmental and economic sustainability, it can be defined as sustainable itself. On the contrary, if a strategy is neither environmentally friendly nor economically feasible, its overall degree of sustainability decreases.

Therefore, in the Results Section, each strategy is scored according to its level of environmental and economic sustainability, as shown in Table 2.

Degree of Sustainability Environmental Sustainability		Economic Sustainability		
Low	The impact on the environment is consistent as regards the use of natural resources (materials, water, energy, etc.)	The capex needed to implement the strategy is consistent and characterized by a payback longer than the lifecycle of the building		
Medium	The impact on the environment is comparable to similar buildings	The return on investment (ROI) of the strategy implemented is typically less than a decade		
High	The impact of the strategy on the environment is negligible	The cost needed to implement the strategy can be easily put in the operating budget of the building in use (opex)		

Table 2. Degree of sustainability scores' equivalences.

3.4. Extents and Limitations

The strategies released by the SRS are also assessed in order to highlight any lack present among them with respect to the behavior of infectious diseases presented in the introduction.

Finally, this study is intended to critically review the approach of the SRS with regards to the concept of sustainability itself. Sustainable development was initially defined as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs [61]. This simplification describes a weak sustainability approach, characterized by the possibility to substitute economy and nature to achieve the goal of the highest possible utility for humans [62]. The weak sustainability approach assumes that natural capital and manufactured capital are essentially substitutable and that there are no essential differences between the kinds of well-being they produce. The only thing that matters is the total value of the aggregate stock of capital [63]. This is also reflected in the three pillars of sustainability whose aggregate defines the sustainable development. No restriction on the degree of substitutability between natural and manufactured capital is introduced, thus an economy is considered sustainable if its savings rate is greater than the combined depreciation rate on human-made and natural capital due to the existence of critical thresholds, beyond which any decrease in a physical unit of natural capital cannot

be replaced by an increase in the quantity of other forms of capital [64]. This approach assumes that the substitutability between natural capital and other forms of capital should be strictly limited to the circumstances where the use of the services provided by natural capital does not lead to the irreversible destruction of this capital because its depletion cannot be compensated by investing in other forms of capital [63].

SRS generally promote a weak sustainability approach and accept that economic development can reduce natural capitals. Its implications are discussed in the Discussion Section.

4. Results

This section is intended to show the measures released by the Sustainability Rating Systems to prevent the spread of infectious diseases in indoor spaces. The focus is on WELL, Fitwel and LEED, that have been the only ones to officially publish ad-hoc strategies in response to the COVID-19 pandemic, and that are critically compared at the end.

4.1. WELL Health-Safety Rating

The WELL Building Standard, managed and administered by the International WELL Building Institute (IWBI), is the most common HBRS to implement, validate and measure features that support and advance human health and wellness. WELL was developed by integrating scientific and medical research and literature on environmental health, behavioral factors, health outcomes and demographic risk factors that affect health with leading practices in building design, construction and management [52].

In late March 2020, IWBI's Task Force on COVID-19 and Other Respiratory Infections, a group of nearly 600 public health experts, virologists, government officials, academics, business leaders, architects, designers, building scientists and real estate professionals, was established to support the response to the pandemic. This group identified an important need for a third-party designation that would guide stakeholders towards evidence-based best practices for mitigating the effects of the pandemic and for overcoming this crisis and beyond [65].

As a result, the WELL Health-Safety Rating for Facility Operations and Management was released to help guide organizations to evidence-based best practices for operating through the crisis (immediate strategies), as well as for long-term preparedness on other critical health and safety issues (long-term strategies) [65].

The WELL Health-Safety Rating includes 21 features across the following core areas:

- Cleaning and Sanitization Procedures.
- Emergency Preparedness Programs.
- Health Service Resources.
- Air and Water Quality Management.
- Stakeholder Engagement and Communication.
- Innovation [65].

The detail of each strategy addressed by the WELL Health-Safety Rating is available in the Supplementary Material of the manuscript.

4.2. Fitwel Viral Response Module

Fitwel is another internationally recognized HBRS. Originally created by the U.S. Centers for Disease Control (CDC) and Prevention and U.S. General Services Administration, Fitwel is implementing a vision for a healthier future where all buildings and communities are enhanced to strengthen health and well-being. Currently, the Center for Active Design is the licensed operator of Fitwel, charged with expanding Fitwel to the global market [54].

The Fitwel Viral Response module was developed in direct response to industry demand surrounding the COVID-19 pandemic. It establishes data-driven strategies that mitigate viral transmission, build trust and create healthy environments for all occupants. Those strategies can minimize the spread of any infectious respiratory diseases, including influenza and legionnaires' disease [54].

The Fitwel Viral Response module covers three key topic areas for mitigating infectious disease transmission:

- Enhance Indoor Environments.
- Encourage Behavioral Change.
- Build Occupant Trust [66].

The detail of each strategy addressed by the Fitwel Viral Response module is available in the Supplementary Material of the manuscript.

4.3. LEED Safety First Pilot Credits

Developed by the U.S. Green Building Council (USGBC), Leadership in Energy and Environmental Design (LEED) is the most recognized GBRS. Its first version, LEED for New Construction and Major Renovations, was developed in 1998 and was updated multiple times over the years with a variety of other rating systems. LEED seeks to optimize the use of natural resources, promote regenerative and restorative strategies and maximize the positive and minimize the negative environmental and human health consequences of the building industry. The ongoing improvements also aim toward high-quality indoor environments for building occupants [67].

In summer 2020, USGBC released six LEED pilot credits to help building teams provide healthy spaces, and to assist with re-entry. The pilot credits outline sustainable best practices that align with public health and industry guidelines related to cleaning and disinfecting, workplace re-occupancy, HVAC and plumbing operations and pandemic preparedness and response [68].

The first four credits are specifically developed for certified LEED projects or undergoing certification, while the last two are available for LEED for Cities and Communities [68].

The detail of each strategy addressed by the LEED Safety First Pilot Credits is available in the Supplementary Material of the manuscript.

4.4. Other Sustainability Rating Systems

WELL, Fitwel and LEED developed specific ratings, modules and credits as best practices for mitigating the spread of COVID-19 and to prevent, prepare and recover from any respiratory disease.

Other globally recognized Sustainability Rating Systems have underlined the most effective measures to respond to the pandemic among the strategies already implemented in the Ratings.

The Building Research Establishment (BRE), responsible for the first ever GBRS Building Research Establishment Environmental Assessment Method (BREEAM), recently published the paper "Building back better with BREEAM" to support the green recovery. BREEAM enhances public health and wellbeing, an equitable built environment and resilience to support a better future and a preparedness for any pandemic scenario [50].

The Regenerative Ecological, Social and Economic Targets (RESET) is an international performance standard and certification program for healthy buildings based on data that are collected and analyzed on a daily basis [69]. Although it is currently impossible to measure airborne viruses in real-time, it is possible to measure a building's ability to minimize the potential of infection from airborne (in particular aerosol) transmission in real-time across a range of parameters. After months of research, RESET released two Indexes focused on optimizing indoor environments against airborne viral infections. The RESET Index for Building Optimization calculates the optimal Indoor Air Quality environment, while the RESET Index for Airborne Infection Potential calculates the potential for infection based on the Indoor Air Quality metrics that can be controlled by a building's or indoor space's air system. The results enable users to gain insight into an indoor space's level of optimization based on a few Indoor Air Quality metrics (temperature, humidity, carbon dioxide and airborne particles) [51].

4.5. Comparison of the Strategies

As shown in the previous chapters, the SRS that released ad-hoc strategies in response to COVID-19 are WELL, Fitwel and LEED. They are available in detail in the Supplementary Material of the manuscript. For each measure analyzed, Table 3 summarizes its scope and category, that are helpful to identify similar strategies between the different SRS (i.e., Support Handwashing in WELL and Hand Hygiene in Fitwel).

Table 3. Sustainability Rating Systems' strategies in response to the COVID-19 pandemic.

Rating System	Strategy	Scope	Category	Sustaina Environment	bility Economic
WELL	Support Handwashing	Cleaning and sanitization	Built Environment	High	High
VV ELL	Reduce Surface Contact	Cleaning and sanitization	Built Environment	High	Medium
WELL	Select Proformed Cleaning	Cleaning and sanifization	built Environment	High	High
WELL	Products	Cleaning and sanitization	Built Environment	High	Medium
WELL	Reduce Respiratory Particle Exposure	Cleaning and sanitization	Built Environment	High	Medium
WELL	Develop Emergency Preparedness Plan	Emergency Preparedness Programs	Built Environment	High	High
WELL	Create Business Continuity Plan	Emergency Preparedness Programs	Company Policy	High	High
WELL	Plan for Healthy Re-Entry	Emergency Preparedness Programs	Company Policy	High	High
WELL	Provide Emergency Resources	Emergency Preparedness Programs	Company Policy	High	High
WELL	Bolster Emergency Resilience	Emergency Preparedness Programs	Company Policy	High	High
WELL	Provide Sick Leave	Health Service Resources	Company Policy	High	Medium
WELL	Provide Health Benefits	Health Service Resources	Company Policy	High	Medium
WELL	Support Mental Health Recovery	Health Service Resources	Company Policy	High	Medium
WELL	Promote Flu Vaccines	Health Service Resources	Company Policy	High	Medium
WELL	Promote a Smoke-Free	Health Service Resources	Company Policy	High	High
WELL	Assess Ventilation	Air and Water Quality Management	Built Environment	Medium	Low
WELL	Assess and Maintain Air Treatment Systems	Air and Water Quality Management	Built Environment	High	Low
WELL	Develop Legionella Management Plan	Air and Water Quality Management	Built Environment	High	Medium
WELL	Monitor Air and Water Quality	Air and Water Quality Management	Built Environment	High	High
WELL	Manage Mold and Moisture	Air and Water Quality Management	Built Environment	High	High
WELL	Promote Health and Wellness	Stakeholder Engagement and Communication	Company Policy	High	High
WELL	Share Food Inspection Information	Stakeholder Engagement and Communication	Company Policy	High	High
Fitwel	Enhanced Indoor Air Quality Policy	Enhance Indoor Environment	Built Environment	Medium	Low
Fitwel	Humidity Control Policy	Enhance Indoor Environment	Built Environment	Medium	Medium
Fitwel	Enhanced Indoor Air Quality Testing and Monitoring Protocol	Enhance Indoor Environment	Built Environment	High	Low
Fitwel	Legionella Water Management Plan	Enhance Indoor Environment	Built Environment	High	Medium
Fitwel	Enhanced Cleaning, Disinfecting, and Maintenance Protocol	Enhance Indoor Environment	Built Environment	High	High
Fitwel	Enhanced Green Purchasing Policy	Enhance Indoor Environment	Built Environment	High	Medium
Fitwel	Surface Hygiene Stations	Encourage Behavioral Change	Built Environment	High	Medium
Fitwel	(PPE) Guidelines	Encourage Behavioral Change	Company Policy	High	High
Fitwel	Personal Protective Equipment (PPE) Provision Plan	Encourage Behavioral Change	Company Policy	High	Medium
Fitwel	Hand Hygiene	Encourage Behavioral Change	Company Policy	High	Medium
Fitwel	Health Promotion Signage	Encourage Behavioral Change	Company Policy	High	High
Fitwel	Specialized Health Programming and Services Plan	Encourage Behavioral Change	Company Policy	High	Medium

Rating System	Strategy	Scope	Category	Sustainability	
				Litviionment	Leononne
Fitwel	Social Support Groups	Encourage Behavioral Change	Company Policy	High	High
Fitwel	Contagious Disease Outbreak Preparedness Plan	Build Occupant Trust	Company Policy	High	High
Fitwel	Business Continuity	Build Occupant Trust	Company Policy	High	High
Fitwel	Mental Health First Aid	Build Occupant Trust	Company Policy	High	High
Fitwel	Viral Response Design Guidelines	Build Occupant Trust	Company Policy	High	High
Fitwel	Enhanced Stakeholder Collaboration Plan	Build Occupant Trust	Company Policy	High	High
Fitwel	Communication Plan	Build Occupant Trust	Company Policy	High	High
Fitwel	Paid Sick Leave Policy	Build Occupant Trust	Company Policy	High	High
Fitwel	Family Support Policy	Build Occupant Trust	Company Policy	High	High
LEED	Re-Enter Your Workspace	Building Operation	Built Environment	High	Medium
LEED	Cleaning and Disinfecting Your Space	Building Operation	Built Environment	High	Medium
LEED	Managing Indoor Air Quality during COVID-19	Building Operation	Built Environment	Medium	Low
LEED	Building Water System Recommissioning	Building Operation	Built Environment	High	Medium
LEED	Pandemic Planning	Cities and Communities	Company Policy	High	High
LEED	Social Equity in Pandemic Planning	Cities and Communities	Company Policy	High	High

Table 3. Cont.

In addition, according to the scoring procedure described in the Table 3 shows the environmental and economic sustainability ratings of each strategy, considering that the social sustainability is always the main target. The "decomposition" of the concept sustainability in its three pillars allows to determine its overall level in a methodic way, even if it represents a simplification.

5. Discussion

As explained in the Methodology Section, SRS generally promote a weak sustainability approach and accept that economic development can reduce natural capitals. This decreases their capability to measure sustainability in the long term [45]. In fact, SRS are characterized by a difficult integration among different criteria that are only compared with benchmark values (e.g., sustainable sites, water consumption, energy and atmosphere, indoor environmental quality) [70]. Considering the unscientific selection of the criteria, their weights and the benchmarks, this critique is difficult to overcome. Moreover, the aggregated level of assessment, which synthesizes the evaluation in one single rate, reduces the ability to deliver a robust and transparent output [71]. In fact, the use of aggregated rates as outcome of the assessment allows different choices, without being able to map them [45].

Even with its limitations, this study reviews the strategies of the SRS that are globally recognized tools to assess building sustainability due to their solidity and applicability that has fostered their diffusion; to show an extent, in September 2021, almost 140 thousand buildings are registered under LEED all around the world [72].

In the literature, several studies already explore the evolution of Sustainability Rating Systems and their multi-criterion nature based on indicators and benchmarks [49]. However, this is the first research that critically investigates the evidence-based best practices developed to mitigate the spread of infectious diseases and their level of sustainability.

In 2020, WELL, Fitwel and LEED released different evidence-based strategies in response to COVID-19 and other infectious diseases, whose comparison is shown in Table 3.

Regarding the scope of application, WELL is divided in five groups, Fitwel in three and LEED in two. Even if the structure is different, they address similar measures, that are almost identical in the case of the two HBRSs, WELL and Fitwel. Figure 3 shows the relationships within the categories of the three SRS analyzed. Fitwel's strategies addressed in the "Enhance Indoor Environment" category are similar to the ones addressed by WELL's "Air and Water Quality Management" and "Cleaning and Sanitization", and they directly impact the "Building Operation" as shown in LEED. On the other hand, LEED's "Cities and Community" category mainly refers to Fitwel's "Encourage Behavioral Change" and "Build Occupant Trust". These aspects are reflected in most of WELL's categories, but especially in "Cleaning and Sanitization Procedures", "Emergency Preparedness Programs", "Health Service Resources" and "Stakeholder Engagement and Communication".



Figure 3. Relationship between the SRS' groups of strategies.

The main concepts considered in WELL and not in Fitwel are food and vaccines. On the other hand, Personal Protective Equipment is strongly addressed in Fitwel while not in WELL. Among the GBRS, only 6 strategies are addressed in LEED, whose extent is obviously limited.

Table 3 also splits the strategies in two main categories: the ones directly related to the built environment (e.g., increased ventilation rates), and the ones that address company policies and are mirrored in the operation and maintenance of indoor spaces (e.g., promote smoke-free environments).

In addition, Table 3 shows the degree of environmental and economic sustainability of each strategy, that already has the highest level of social sustainability, since it is conceived to enhance the human health and safety. Even though the decomposition in the three bottom lines represents a simplification of the concept sustainability, it allows to determine the overall level of sustainability of each strategy in a more methodic and accurate way.

Strategies related to the built environment have a higher environmental and economic impact, thus their environmental and economic sustainability is lower. On the contrary, company policies are easier to implement because they are typically preventive measures (i.e., developed before the emergency), while measures applied to the built environment are typically corrective (i.e., applied during the emergency).

Preventive measures are likely to be adopted at early stages because their implementation is feasible, as explained in Tables 2 and 3. Due to their sustainable nature, they are also expected to become part of the state-of-the-art in the future, like the strategies described in Table 1, which shows the measures commonly present in modern buildings and introduced with the spread of previous historical infectious diseases.

During emergency situations such as pandemics, strategies referred to the built environment may be adopted in order to guarantee the normal building operation and business continuity. However, these strategies should be put in place only in extreme conditions because they cannot be structural due to their lower level of sustainability. For instance, higher ventilation rates require a higher energy need. If the energy generation is on-site, Human conditions and behavior are strongly related to infectious transmission and symptomatology. As mentioned, people with concomitant pathologies or with an irregular circadian rhythm have a weaker immune system and therefore are more exposed [15–18]. Personal Protective Equipment, social distancing and lockdown of the population are among the most direct and precautionary measures to be taken according to WHO.

SRS aim to ensure that building occupants are safe in their spaces, but also that mutual trust is formed between building occupants and managers, in which everyone does their part to protect and maintain their own health, as well as the well-being of those around them.

However, the strategies developed lack in addressing social distancing in a detailed way. For instance, there are not specific credits that analytically address maximum occupancy rates to minimize airborne cross-infection. This is surprising, considering that the latest experiments highlight that the airborne transmission route is largely the most common [28,29]. In particular, WELL and LEED appear to lack strategies that numerically mark provision of restricted access to common areas in addition to maximum occupancy rates in indoor spaces to maintain the recommended physical distancing of 2 meters [80].

6. Conclusions

Since the COVID-19 outbreak, buildings have been viewed as a facilitator of disease spread, where the three main transmission routes (contact, droplets, aerosols) are more likely to happen. However, with proper policies and measures in place, buildings can be better prepared for re-occupancy and beyond. If spaces are resilient, their level of sustainability increases and their features are expected to become part of the state-of-the-art in the future, such as the strategies adopted in modern buildings that were originally introduced in response to infectious diseases of the past.

This study reviewed the strategies specifically released by the Sustainability Rating Systems (SRS) WELL, Fitwel and LEED to create indoor environments that can respond to COVID-19 or other respiratory infections. These best practices are internationally applicable, voluntary and focused on the operation of mechanical ventilated office buildings. However, assets that do not fall under these categories (e.g., buildings under construction, retail assets, etc.) may also follow the recommended strategies from early stages to enhance an integrated design process.

The review highlighted that:

- Company policies show a higher environmental and economic sustainability compared to the strategies directly related to the built environment because they are preventive rather than corrective measures.
- The measures addressed by WELL, Fitwel and LEED are similar even though the structure of the SRS is different.

However, the study also underlined several limitations:

- The SRS promote a weak sustainability approach that accepts that economic development can reduce natural capitals.
- The Criteria of the SRS are only compared with benchmark values whose aggregated level of assessment does not allow to map different choices.
- There is a general lack of analytical strategies that address occupancy rates and physical distancing, whose importance is shown in the latest research where the airborne transmission stands out as the main route of infection.
- Fitwel lacks in considering the implications of food and vaccines.
- WELL does not consistently address Personal Protective Equipment.
- LEED is the less solid with only 6 strategies.

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