

SUSTAINABILITY AND RESILIENCE IN BUILDING DESIGN: DISCUSSION ON TWO CASE STUDIES

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ABSTRACT. Designing sustainable and, at the same moment, resilient buildings is a necessity to reach the UN Sustainable Development Goals by 2030. However, these two building design approaches – sustainability and resilience – are usually treated separately. Typically, resilience-improving strategies are placed only after a disruptive event and not at the design stage. It is clear that there is a substantial intersection between sustainability and resilience and this manuscript aims to determine more precisely the commonalities and contradictions seen in building design sustainable and resilient approaches as crucial elements for improving their cooperation in buildings. To accomplish this, the authors qualitatively analysed two case studies – respectively claiming to be sustainable and resilient – to understand if a sustainable building can also be considered resilient and vice versa. This paper is addressed to the private and public sectors that have a decisive role in building design and are determined to take tangible steps to influence decision-making and resilience-based solutions already at the design phase. In conclusion, once the commonalities of resilience and sustainability are highlighted, a building designed as sustainable or resilient will be in line with both long-term perspectives.

KEYWORDS: Building design, sustainable building, resilient building, synergies, contradictions, future threats.

1. INTRODUCTION

In the 6th assessment report of the Intergovernmental Panel on Climate Change (IPCC) [1], it is highlighted that Earth is experiencing irreversible impacts and unprecedented warming, including more frequent and more extreme weather events; their consequences will continue to get more intensive for every bit of warming [2]. The frequency and severity of floods, wildfires, heat and cold waves, and droughts in the last decade was increasing, causing remarkable economic costs and life losses [3, 4]. The IPCC's report shows that emissions of greenhouse gases from human activities are responsible for approximately 1.1 °C of warming since 1850–1900 and significantly contributes to the alteration of the local climatic conditions in the built environment (i.e. urban heat islands) [2]. In Europe, buildings are the largest energy consumer, responsible for approximately 40 % of greenhouse gas emissions; indeed, the built environment represents a crucial sector in terms of saving potential and, at the same time, one of the most vulnerable and densely inhabited places affected by climate change effects.

1.1. SYNERGIES BETWEEN SUSTAINABILITY AND RESILIENCE

Developing the built environment sustainable and resilient to climate change is a pressing global need, as outlined by the 2015 Paris Agreement [5] and the recent 2021 IPCC assessment report [2]. Sustainability has been a trend since the '90s, when different protocols aimed at assessing sustainability in buildings were developed, such as Leadership in Energy and Environmental Design (LEED) [6] in the United States, Building Research Establishment Environmental Assessment Method (BREEAM) [7] in the United Kingdom, and Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) [8] in Germany. The current concept of resilience is instead less concrete and much more recent than sustainability. There is no fixed definition, but it is starting to experience a global increment in interest due to the climate change impacts [9]. However, the most accepted and common explanation defines resilience as the ability of a system to maintain or recover functionality in the event of disruption or disturbance [10, 11]. The need for effective strategies to face these interconnected challenges arises in the 2015 UN Sustainable Development Goals (SDGs), where adequate mitigation and adaptation measures are expected to be introduced by 2030 [12].

In particular, the targets of SDG 13 are aimed at increasing resilience from natural hazards, while others, such as SDG 7 or 11, are more focused on sustainability. However, SDGs always share benefits and synergies and are directly connected to sustainability and resilience for the built environment. Thus, it is highlighted that both resilience and sustainability can have commonalities at the building level and should be considered already at the design stage.

Accordingly, green buildings should be designed to be resilient to extreme events (loads connected to heavy rains, floods, or other hazards) to keep the occupants safe and reduce the environmental impacts associated with post-event adjustments [13].

1.2. SCOPE OF THE PAPER

Using two case studies, the paper aims to analyse sustainability and resilience in building design via a qualitative assessment. Qualitative analysis is suited to the initial phases of planning, object programming, and designing at every stage of the design process [14].

The first case study is a LEED-certified building ranked Platinum (LEED New Construction v3) among the very new generation of sustainable construction in the Czech Republic; the second is a resilient building completed in New York City following a new protocol developed as a response to the 2012 Sandy hurricane consequences. After preliminary identification of the distinctive criteria associated with sustainability and resilience, the buildings were assessed qualitatively to understand if the claimed as sustainable is also resilient and vice versa. Thus, the main scope is to understand the relationship between sustainability and resilience to design principles.

2. MATERIALS AND METHODS

The adopted method includes a qualitative assessment for two case studies considering different criteria both for sustainability and resilience. The qualitative assessment approach is quite consolidated in the scientific literature as a source of universal methods for investigating whole objects and selected elements of the building [14].

In the case of sustainability, the criteria were selected analyzing the most known and worldwide sustainable protocols for New Construction: LEED v4.1 [6], BREEAM International 2016 [7] and DGNB 2020 [8]. Once the criteria and the benchmarks were picked, four levels of accomplishment (poor, sufficient, good and excellent) were selected to assess the specific criterion's level of achievement (Table 1).

A similar method has been considered in the case of resilience where RELi [15] and Envision v3 [16], two of the most known resilience assessment tools worldwide, have been chosen as reference tools for selecting the criteria (Table 2).

The benchmarks for the distribution of the grades were established using different methodologies aligned with benchmark values found in the literature that

are explained case by case [7, 15, 17, 18]. Dependent on fulfilment of each criterion, points were given according to this scale: 2 points for "Poor", 5 points for "Sufficient", 8 points for "Good" and 10 points for "Excellent". It is assumed that buildings in which poor positive pro-environment or resilient measures were applied for the assessed criteria receive a satisfactory grade of 2. Consequently, the maximal value is set as 130 (respectively 70 for sustainability and 60 for resilience), which means that the building has a very excellent performance in terms of qualitative aspects.

For research purposes, we considered two case studies located in flood-prone areas:

- Main Point Karlin (Prague, Czechia) (Figure 1a) – LEED-certified office building (LEED v3); it was the first Platinum-certified building in Czechia and even Central Europe. It was built in 2012 in the Karlin neighborhood, an area really close to the Vltava river. It has been chosen because one of the first examples of a new generation of buildings in the Czech Republic – it achieved great results, particularly in the fields of energy utilization, indoor environmental quality and innovations.
- Dock 72 (Brooklyn, New York City) (Figure 1b) – Class A office building claimed to be flood-resistant. It was built in 2019 in the Brooklyn Navy Yard neighborhood, an area in front of the Navy Yard Bay. It has been chosen since it is a response building to the 2012 Sandy hurricane damages; the building hovers above the floodplain on V-shaped columns – it achieved great performance, particularly in the fields of energy back-up and passive systems.

Finally, a table with grades for every criterion gives a picture of the sustainability or resilience of both case studies.

2.1. BUILDINGS DESCRIPTIONS

2.1.1. SUSTAINABLE BUILDING CASE STUDY

The building chosen as a case study for representing sustainability is the Main Point Karlin office building, located in Prague (Czechia) (Figure 1a), in the neighbourhood of Karlin, in front of the Vltava river. The building was awarded the title "Best Office Building in the World" at the MIPIM Awards 2012 and the first holder of the highest LEED Platinum certificate in Central Europe (certified under LEED New Construction 2009). Main Point Karlin is a technologically equipped 10-floors office building with a leasable area of 22 000 m². The distinctive facade panels have the function of sun breakers, ensuring optimal workplace lighting by direct and indirect components. The coloured material used in the facade is fiberC, which was considered one of the greenest concrete panels available in 2012 with low embodied environmental impacts (202 MJ/m² for primary energy and 14 kg CO₂eq/m² for global warming potential). Moreover, a 1 200 mm diameter flushing channel runs through the basement of the building and in

Criteria	Poor	Sufficient	Good	Excellent
Connectivity and Transport	Public traffic connection > 1 km	Public traffic connection within 1 km	Public traffic connection within 800 m	Public traffic connection within 400 m
Land use and ecology	Using native vegetation	Green roof and native vegetation	Previous plus installed rainwater collection system	All the techniques before mentioned and other innovative solutions
Reduction of indoor water consumption	> 0 %	> 30 %	> 40 %	> 50 %
Improvement of energy performance (compared to the baseline building performance)	> 5 %	> 20 %	> 30 %	> 40 %
Resource-efficient and circular material life cycles	Surface area reused > 0 %	Surface area reused > 25 %	Surface area reused > 50 %	Surface area reused > 75 %
Renewable energy procurement	> 2 % (on-site) > 20 % (off-site)	> 5 % (on-site) > 30 % (off-site)	> 10 % (on-site) > 40 % (off-site)	> 20 % (on-site) > 50 % (off-site)
Daylight	< 55 % of occupied floor area	55 % of occupied floor area	75 % of occupied floor area	90 % of occupied floor area

TABLE 1. Compilation of criteria for the evaluation of qualitative aspects related to sustainability.

Criteria	Poor	Sufficient	Good	Excellent
Building surroundings protection	Reduced run-off	Develop Nature-based Solutions that protect the surrounding	Plan system for 100-year floods for the building	Protect below ground system vents and entrance from floods and 100-year floods for the surrounding
Passive heating	Only active solutions	Direct gain via glazing	Direct gain via storage + glazing	All the strategies mentioned + indirect gain via sunspace
Passive cooling	Orientation	Orientation, cross ventilation	Solar shading, building facades	All the strategies mentioned
Passive lighting	Minimum daylight	Daylight from multiple sides	Intermediate light shelves and skylights	All the strategies mentioned
Water harvesting	None	< 50 % of the roof area	> 50 % of the roof area	> 50 % of the roof area and parking areas for reuse
Resilience to climate/natural hazards	None	Identification of regional hazards	Location hazards assessment + passive solutions	Location hazards assessment + passive solutions and resilience emergency plan

TABLE 2. Compilation of criteria for the evaluation of qualitative aspects related to resilience.



(A).



(B).

FIGURE 1. (A) Main Point Karlin, Prague (Czechia), designed by DAM Architekti. Details of the façade that works as sun shading. (B) Dock 72 at the Brooklyn Navy Yard (NYC), designed by S9 Architecture.

which the Vltava flows from the Těšnov weir to the Libeň docks. This technology is used to cool the building passively.

The quality of the building's indoor environment, corresponding to a higher standard, is ensured by ceiling induction units. The under-ceiling placement of the units is ideal in terms of natural airflow – the cooled air falls by its weight and does not “blow” on the workers from anywhere. However, even if it is located in proximity to the Vltava river, it does not consider any strategies against flood-related events since its ground floor, where restaurants, bars and even the main entrance are placed, is below the street level.

2.1.2. RESILIENT BUILDING CASE STUDY

The building chosen as a case study for representing resilience is the Dock 72 office complex, located in Brooklyn (NYC) (Figure 1b), on the waterfront of the East River. The 62 700 m² structure, whose base uses steel frames and steel braced cores, has 16 floors looking out to Brooklyn and Manhattan, situated 0.3 m above the floodplain. The city of New York experienced the devastation of the hurricane Sandy in 2012 that led to a full collapse of the electric system and flooding all around the five neighbourhoods, mainly in Manhattan and Brooklyn. This Class-A office building is designed to withstand potential hazards, such as flood events and sea-level rise, with the 20 V-shaped columns allow water to flow under the building and sloping ramps that provide access to the elevated main floor. The building's mechanical systems are raised above the first level, ensuring that the building functional level can be preserved or reloaded easier in the recovery phase.

The Dock 72 indoor environment is characterized

by open, flexible, and light-filled workspaces. The stepped massing and gridded, glazed façade maximizes the views on the Manhattan bay and allows a direct gain of sunlight.

3. RESULTS AND DISCUSSION

3.1. QUALITATIVE ASSESSMENT OF THE TWO CASE STUDIES

3.1.1. SUSTAINABILITY QUALITATIVE EVALUATION

As it was previously mentioned in Section 2, each case study was analysed to understand the general sustainability of the building. The qualitative sustainability evaluation considers seven main categories that are listed in Table 3.

Main Point Karlin presents great outcomes in the categories of Connectivity and Transport, since public transport services are very close to the building, and in Land Use and Ecology, since the building is placed on a former brownfield, successively redeveloped, and a rainwater collection system that allows to a 100 % reduction in potable landscape water use. In contrast, the category that presents the lower grade is Resource-efficient and circular material life cycles due to only 20 % recycled content building materials.

Dock 72 in Brooklyn showcases an excellent result in Connectivity and Transport since the proximity of various available transport services and good results in Energy performance and Daylight thanks to energy-saving measures that include increased roof and exposed floor insulation, reduced fan power and variable frequency drives, and high-performance building envelope and reduced lighting power centre. Quite the reverse, two of the seven selected sustainability categories are graded as “poor” because there are

	Main Point Karlin	Dock 72
Connectivity and Transport	Excellent	Excellent
Land use and ecology	Excellent	Sufficient
Reduce indoor water consumption	Good	Sufficient
Improvement of energy performance	Good	Good
Resource-efficient and circular material life cycles	Poor	Poor
Renewable energy procurement	Sufficient	Poor
Daylight	Good	Good

TABLE 3. Qualitative assessment for sustainability criteria.

	Main Point Karlin	Dock 72
Building surroundings protection	Poor	Excellent
Passive heating	Sufficient	Excellent
Passive cooling	Excellent	Sufficient
Passive lighting	Excellent	Sufficient
Water harvesting	Good	Sufficient
Resilience to climate/natural hazards	Poor	Excellent

TABLE 4. Qualitative assessment for resilient criteria.

no renewables on-site and no intentions of building material reuse.

3.1.2. RESILIENCE QUALITATIVE EVALUATION

As it was previously mentioned in Section 2, each case study was analysed to understand the general resilience of the building. The qualitative resilience evaluation considers six main categories that are listed in Table 4.

Main Point Karlin presents, on one side, great outcomes in the categories of Passive Cooling thanks to the 1200 mm pipe that runs through the entire building from the Vltava river, and in Passive Lighting, the orientation of the building and the characteristic coloured pillars that also work as sun breaker. On the other side, two categories present the lower grade: Transportation system protection and Resilience to climate/natural hazards.

Dock 72 was designed with a special focus on flood-resilient features to potentially face another catastrophic event like the 2012 hurricane. The ground floor was built 0.3 meters above the 100-year flood-plain grade. A 1500 kW emergency generator ensures that tenants, even in case of extreme events and consequent black-out, would not experience a lack of light or heating.

3.1.3. COMPARISON

Figure 2 shows the two graphs related to the qualitative sustainability assessment (7 categories) and resilience (6 categories) of the two case studies.

As it was preannounced, the building claimed to be sustainable, Main Point Karlin, has greater results than the one claimed as resilient, Dock 72, because more categories are under the grades “Excellent” or “Good”, such as Land use and Ecology and Reduce of indoor water consumption thanks to run-off reduction

and rainwater harvesting system. However, Dock 72 presents the same great results for Connectivity and Transport as the Prague building, thanks to the closeness of different available public transportation (ferry, bus, metro, and bicycle lanes), while it lacks in reusing of building materials and recycling.

Focusing on the qualitative resilience assessment, Dock 72 presents excellent outcomes for three of the six categories, mostly due to its design thought to be flood-resistant. Indeed, placing the main entrance and the mechanical systems at higher levels allow the building’s functional level to be preserved or reloaded easier in the recovery phase in the presence of heavy rain or other climate-related hazards.

In 2002, a 100-year flood event caused by over a week of continuous heavy rains ravaged Central Europe. Prague received significant damage; Karlin was one of the most severely affected capital city neighbourhoods, with a risk of building collapse. However, as shown in Figure 2, Main Point Karlin, built in 2012, precisely ten years after the catastrophic flood, does not present any strategy to face such a possible event that is even more potentially dangerous due to river proximity. However, it showcases great results for passive strategies for cooling, thanks to the tube of Vltava water that runs on the second-unground floor, and for lighting, due to the particular façade panels.

3.2. LIMIT OF THE STUDY

The limit of this study is related to the subjectivity of the adopted criteria used for assigning the grades. The list of indicators is limited and simplified but inclusive and clusters some sub-indicators that, otherwise, would expand the comparative process without focusing on the core point of finding a balance between sustainability and resilience. That allowed even

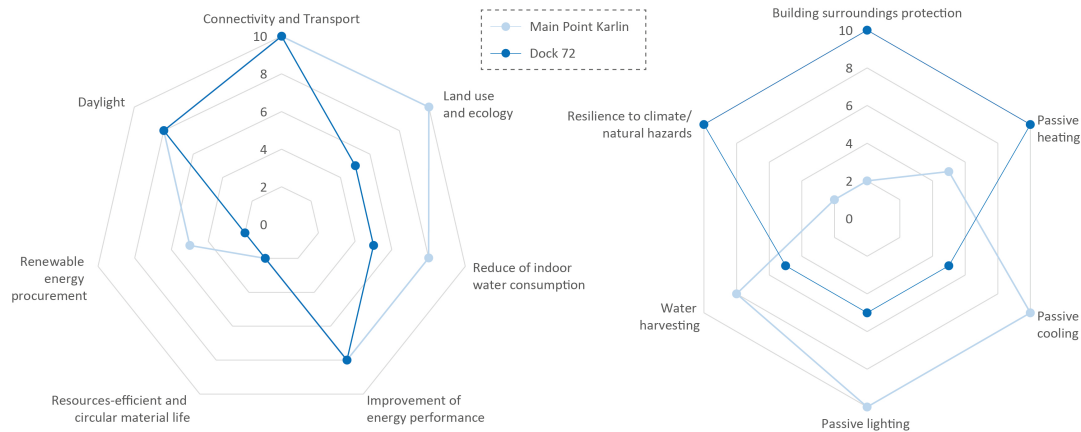


FIGURE 2. Analysis of the two case studies for sustainability (left) and resilience (right) according to the defined criteria.

to keep complexity manageable, as (1) other assessment frameworks (and even those that inspired the selection) consider other variables that could change the overall assessment result and (2) some of them are highly criticized “attribute-oriented” rather than “performance-oriented” criteria. However, these clusters address sustainability and mostly environmental resilience while not considering other aspects of resilience, such as economic or social. Still, these aspects will be studied in further studies.

4. CONCLUSION

The approach that has been adopted serves to identify common elements and distinctive attributes for sustainability and resilience so that these specific solutions can be exported or imported between the two domains to design a new generation of buildings.

As the results highlight, it is possible that if in a building only sustainability is considered, some resilience aspects may be neglected and/or when only principles of resilience are taken into consideration, some fundamental sustainability values may be ignored. The primary outcome of this work is that it is necessary to think about a new generation of buildings where both domains are considered to find a proper balance between them.

Finally, it is possible to conclude that some indicators must be identified and become irreplaceable in guiding the design so that a building, in addition to having minimal elements of sustainability, also contextually can give a minimal response to the concept of resilience since they share common roots. In practice, the final design will depend on the building objectives, which might include more or less severe resilience and/or sustainability requirements. This is in the logic of adapting the principles around which direct the construction sector, particularly the construction of new buildings, with respect to the tomorrow’s challenges, so clearly evoked by the SDGs.

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