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Sustainable and Resilient Architecture: Prioritizing Climate Change Adaptation

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Abstract The purpose of this paper is to emphasize the need for architects to prioritize sustainability and resilience in building design, especially in the face of an increase in the frequency and intensity of natural disasters caused by climate change. Sustainable, climate-adapted, and resilient architecture can reduce greenhouse gas emissions, promote resource efficiency, and improve people's quality of life. This paper explores the design aspects of the top ten COTE projects for 2023 recognized by the American Institute of Architects. These projects emphasize sustainable performance, stormwater and energy reduction strategies, and design-for-change principles. The main objective is to identify how sustainable project design adapts to climate change and supports resilient recovery from disasters. The methodology involves identifying and reviewing design criteria for sustainable performance. It also involves analysing stormwater runoff and energy reduction strategies. It investigates the futuristic vision for design for change, and highlights design innovations accomplished through the selected projects. This paper provides valuable insights into how projects approach adaptive and resilient design through sustainability. Architects can benefit from this holistic approach to designing spaces that adapt to the ever-changing climate and promote sustainable design innovation.

Keywords Design Innovation, Sustainable Performance, Carbon Neutral, Climate Change Adaptation, Disaster Resilience, Survivability Timeline, Critical Infrastructure, Collaborative Design

1. Introduction

The COTE Top Ten Awards are presented annually by the American Institute of Architects (AIA) to honour the 10 most innovative sustainable architecture and design projects that promote sustainable design practices and reduce the impact of built environments on the natural world. The "Top Ten program was founded on the idea that sustainability is essential to design excellence, and vice versa" [1]. Projects that are recognized under this program integrate environmental, social, and economic aspects of sustainability into their design process, and positively impact the community and the environment. The winners of this award include buildings and structures of all types, from public schools to office buildings to residential homes. The awards aim to promote high-quality, sustainable design practices and raise public awareness about sustainability in the built environment. One of the goals of this award is to recognize **design performance over design intentions**. Therefore, the qualifying projects are required to showcase performance and occupant satisfaction data for 12 months or more. The purpose of this criterion is to demonstrate that the actual performance of a project is in line with the anticipated performance and confirm that the project contributes to real-world problems. Transparency is fundamental to these awards so that architects can learn from the successes of the best projects. To "jointly improve our work and realize our shared vision of a healthy, sustainable, and equitable future, all submissions considered under this award are expected to have honest and accurate metrics, narratives, and images, and all claims should be substantiated with evidence" [2].

2. Background

Since 1997 each year, innovative projects have been recognized for their integration of design excellence with environmental performance by the American Institute of Architects (AIA), and Committee on the Environment (COTE). These projects are evaluated on a broad and inclusive definition of design quality that includes performance, aesthetics, community connection and resilience stewardship of the natural environment and innovative solutions that prioritize the well-being of people and the planet. The design and performance of projects are measured in ten areas: projects attempt for design integration, how effectively the project integrates its surrounding community, its contribution to surrounding ecosystems, understanding of the extent to which the project is responsibly managing its water resource, its cost-effectiveness, material choices and inclusion of alternate sources of energy to minimize carbon footprint. It also inquires about how the design promotes the comfort and health of inhabitants, how it adapts to climate change, and supports resilient recovery from disasters. Additionally, it also emphasizes the lessons learned during the projects' design, construction, and occupancy phases. The most recent exemplary performing top ten sustainable architecture projects in the USA are identified under COTE Top Ten Awards for 2023 include the following projects: Casa Adelante 2060 Folsom by Mithun with Y.A. Studio in San Francisco, Confluence Park by Lake Flato Architects+ Matsys in San Antonio, Texas, DPR Sacramento Zero Net Energy Office building by SmithGroup located in Sacramento, California, Harvard University Science and Engineering Complex designed by Behnisch Architekten in Boston, John W. Olver Transit Center by Charles Rose Architects, situated in Greenfield, Massachusetts, RIDC Mill 19: Buildings A & B, by MSR Design with R3A Architecture in Pittsburgh, Science and Environmental Center, by Leddy Maytum Stacy Architects, situated in Hillsborough, California, UC San Diego North Torrey Pines Living & Learning Neighbourhood in San Diego, Watershed building by Weber Thompson in Seattle and Westwood Hills Nature Center by HGA Architects and Engineers at St. Louis Park, Minnesota. Based on the project narratives, it is identified that six out of these ten selected sites belong to previously developed land and the rest four are identified as brownfield developments.

The relevance of the design aspects and the extent of their application in the relevant field of design were analyzed by reviewing the relevant literature before beginning the analysis of connections and links presented in this paper. These design aspects include application of climate-resilient infrastructure, sustainable practices, disaster recovery preparedness, community resilience, adaptation initiatives, and post-disaster recovery planning. In Figure 1, the literature review is presented as a bubble diagram rather than a citation tree to help the reader explore papers relevant to this topic. Based on this literature review, studies suggest that climate change adaptation and resilient recovery from disasters require an integrated approach involving socio-economic development, environmental conservation, and disaster risk reduction, with context-aware methods and collaboration among policy practitioners, and scientific communities. There are several examples of successful climate change adaptation design projects worldwide. However, this paper will focus on the North American examples and is based on the findings obtained from analysing COTE's top ten awarded projects in 2023. The North American region has seen tremendous climate change adaptation development in the past few years. By focusing on North American examples, this paper will provide an in-depth look at innovative solutions developed in this region. On the other hand, COTE's top ten awards serve as a gold standard for recognizing excellence in adaptation design, making them ideal for detailed analysis. As a result, this paper seeks to identify the best practices from projects that provide creative solutions to climate change challenges and how they can be replicated in other parts of the world.

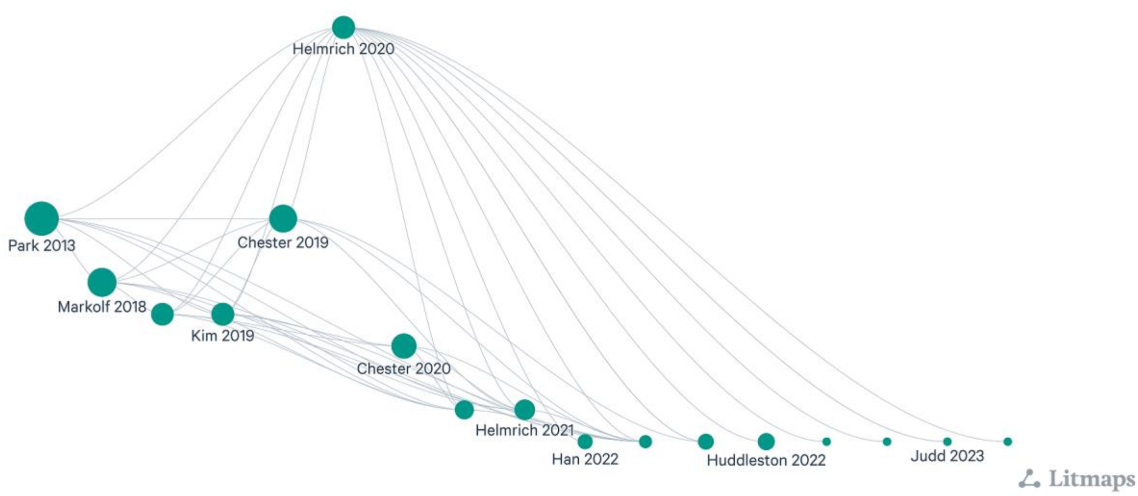

Figure 1. Literature Review (created by author using Litmaps software)

3. Methodology

This paper investigates the design aspects of the top ten COTE projects for 2023. It highlights innovation achieved through design for excellence and sustainable performance, reductions in stormwater runoff and energy, and design for change. Climate adaptation and disaster resilience are incorporated into the selected projects under the heading of design for change. This paper identifies "how project design adapts to climate change, and supports resilient recovery from disasters". The research methodology used in this paper is as follows. This research identifies the COTE top ten projects for 2023 and reviews sustainable performance design criteria. This review will help determine how the selected projects met or exceeded sustainable design criteria. This review analyses stormwater runoff and energy reduction strategies used in the selected projects. This analysis will help determine how projects have achieved sustainable performance through resource reduction strategies. A further analysis of the future vision incorporated into the projects evaluated for design-for-change is presented in the paper. The criteria for design for change is evaluated using critical infrastructures included in the project. This investigation will provide insight into **how projects have adapted to climate change and support resilient recovery from disasters**. Finally, this paper highlights the design innovation accomplished through the selected projects and illustrates how these projects have incorporated design for change while achieving excellence in sustainable design and performance.

This methodology is supported by the Sankey diagram, which is created to visualize connections between projects and the criteria selected for assessment in this paper's methodology. This Sankey Diagram is used to reflect **visible connections** between design aspects including: sustainability performance, critical infrastructure and resource reduction under energy and water use. This connection is further extended to identify the links between resource reduction and survivability timeline. Additionally, this Sankey diagram is used to identify the details of project sites and project building typologies. These details are categorized based on projects functional characteristics to recognize the **invisible connections** between project function and project design. This invisible connection guides the requirement for selected design aspects. This Sankey diagram is represented in Figure 2. This diagram lists all the selected projects, and connects these projects with sustainability performance and critical infrastructure based on the performance score and resiliency score available at the AIA COTE top ten awards website. This critical infrastructure is further connected to resource reduction divided under energy and stormwater, and survivability timelines as the dependent variables of resource reduction. This survivability timeline is further linked to offer insights into projects' functional characteristics categorized under previously developed land and brownfield development and building typologies guiding survivability requirements under educational, office, residential and recreational project typologies.

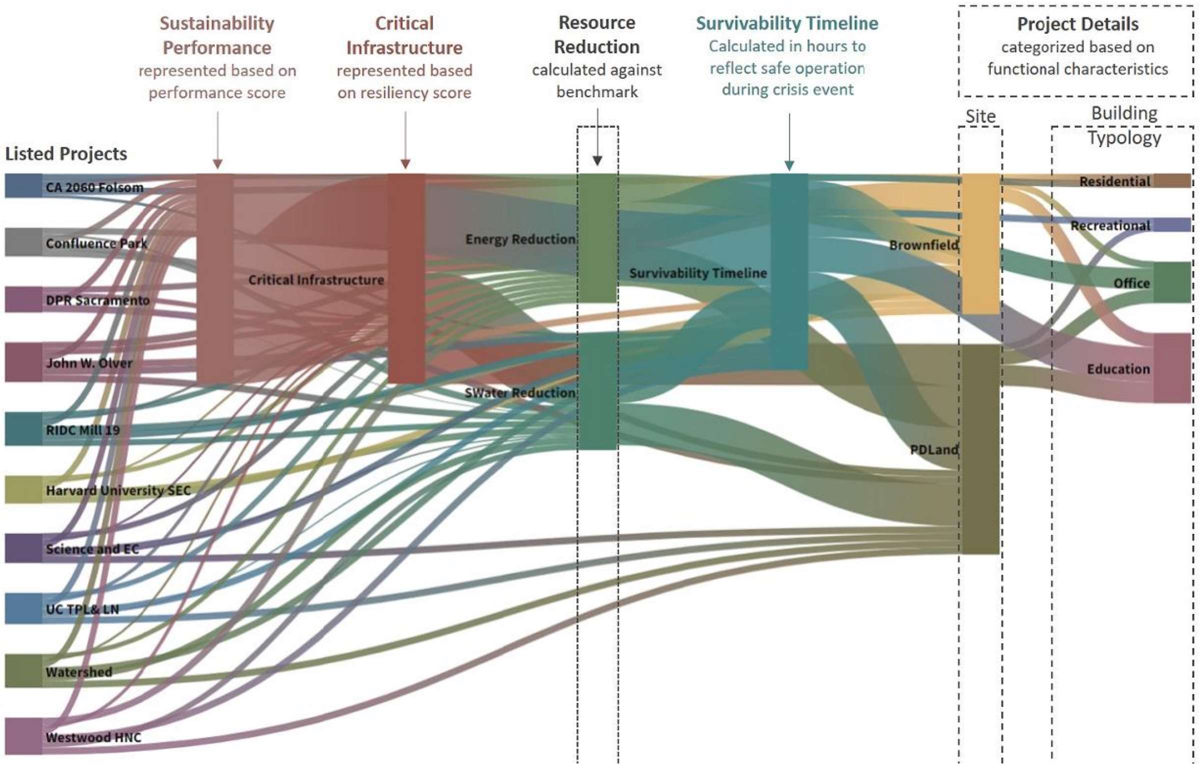

Figure 2. Sankey Diagram to represent visible and invisible connections between design aspects & functional characteristics

4. Discussion

Based on the review of sustainable performance design criteria of COTE's top ten projects for 2023. A word cloud is created to illustrate the overarching design characteristics identified during this criteria review. This word cloud is a visual representation of the data submitted by each selected project to support its sustainable design claims. This word cloud represents words of different sizes based on the number of times they appear in the data. As illustrated in this word cloud Figure 3, bold words like carbon-neutral design, net-zero operations, regenerative design and critical infrastructure are identified as the dominant aspects of design. In architectural design, an aspect or theme represents the "overall abstract design as part of the architectural planning and design process that comes to define the expression of the architecture as a whole" [3]. Terms like forward thinking, community engagement, and survivability are also prominent in this word cloud. These terms indicate the prominence of the design approaches used in the selected projects. The design approach "refers to preconceiving the process steps and priorities before proceeding with the development" of actual design [4]. These terms are used during the initial stages of the design process to set the target for design outcomes. During this review it was identified that these terms help determine how the selected projects will meet or exceed their targeted sustainable design criteria. These terms are indicative of the design guidelines that dictate design values and design attributes in the selected set of projects. These are also responsible for helping project teams establish project goals, identify recommendations on how to apply design principles and provide a positive user experience.

The analysis conducted to investigate resource reduction by design demonstrates how these projects delivered sustainable performance through resource reduction strategies. It was observed through the Sankey diagram that three of the selected projects achieved 90% - 100% energy reduction from the established benchmark. This reduction includes energy offsets achieved using renewable energy sources. These three projects include the Confluence Park, John W. Olver Transit Center, and Westwood Hills Nature Center. The rest of the projects offer energy reductions ranging from 68% to 89% (represented as 0.68 and 0.89 in Figure 4). The highest energy reduction in this range is at Confluence Park with 93%. Seattle's Webber Thomson Watershed Building has the lowest percentage at 68%. This impressive range of energy reductions represented in Figure 4, highlights the potential for building design to make remarkable strides towards sustainability with renewable energy sources. Confluence Park's 93% reduction rate is an impressive example of what can be accomplished in urban parks. In addition to contributing to energy savings, these reductions created through renewable energy sources benefit the environment and create a learning experience for others to follow.

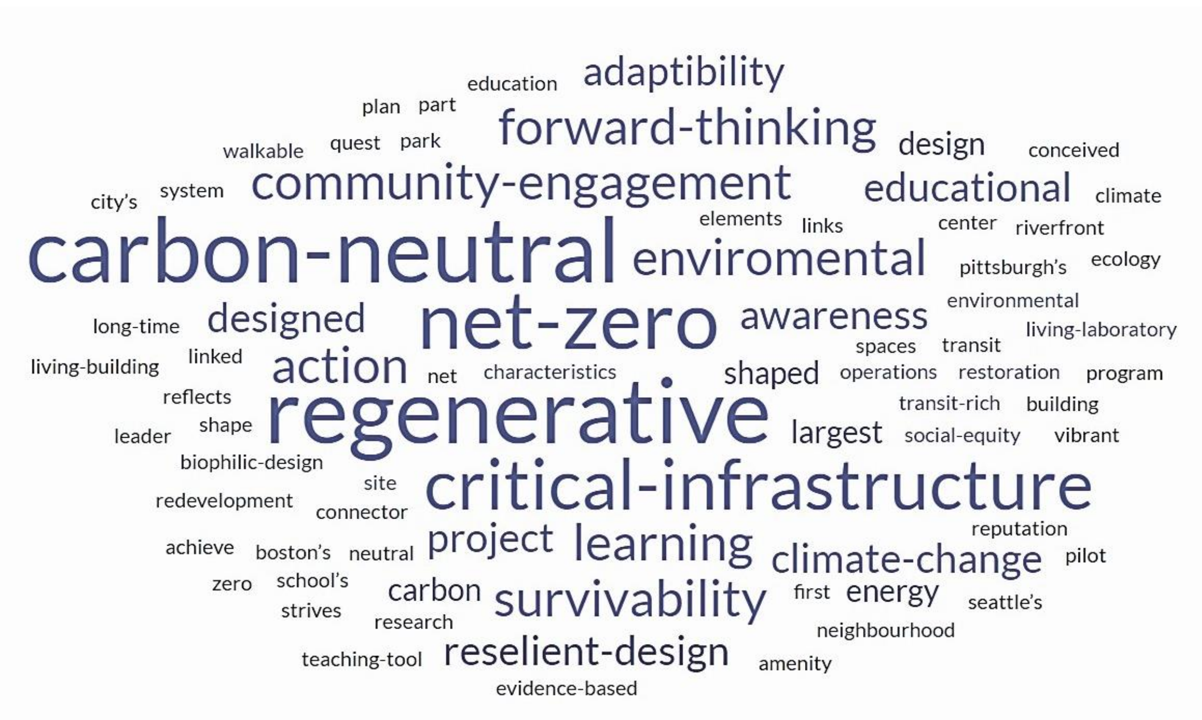

Figure 3. Word Cloud

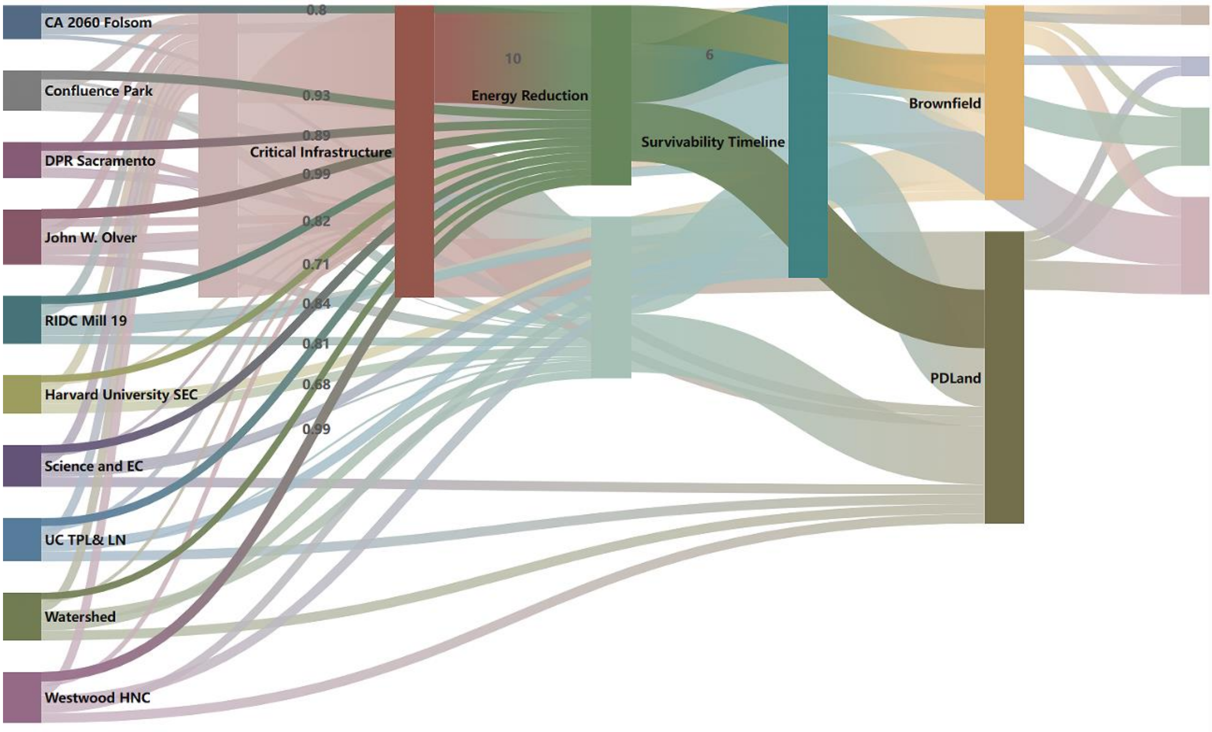

Figure 4. Sankey diagram highlighting energy reduction (reflect visible connections between design aspects and energy resource reduction)

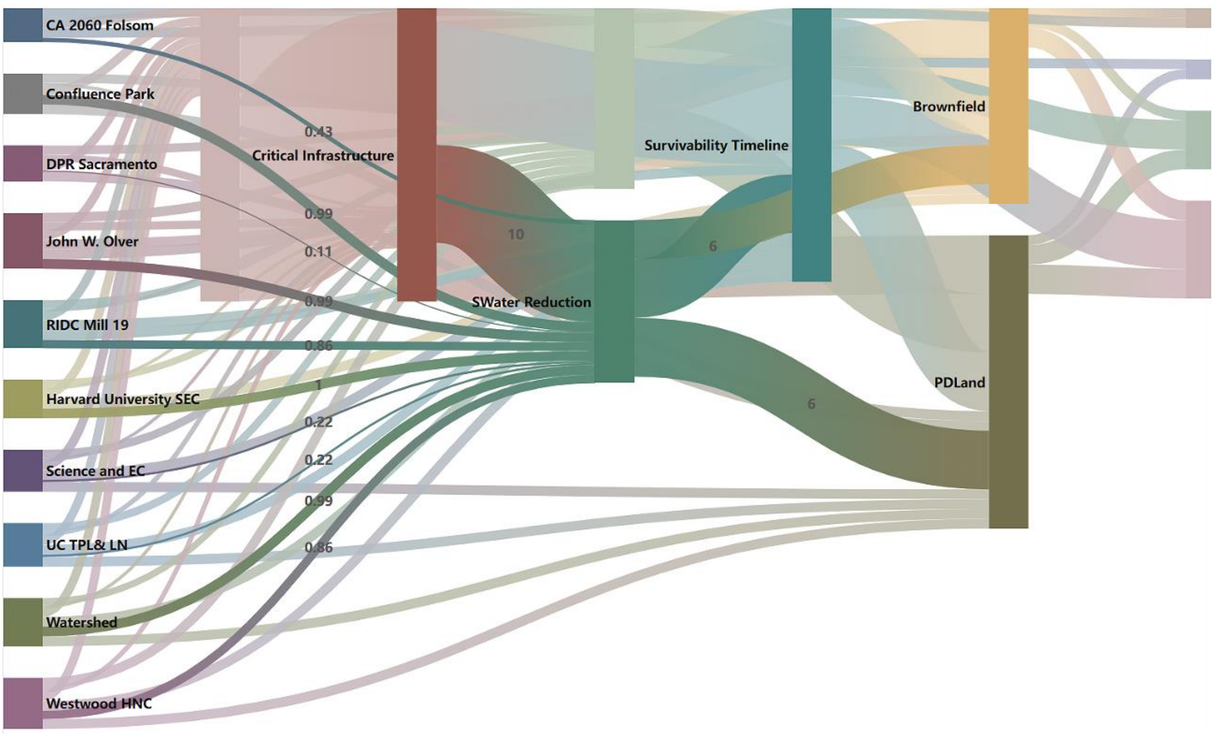

Figure 5. Sankey diagram highlighting stormwater reduction (reflect visible connections between design aspects and water resource reduction)

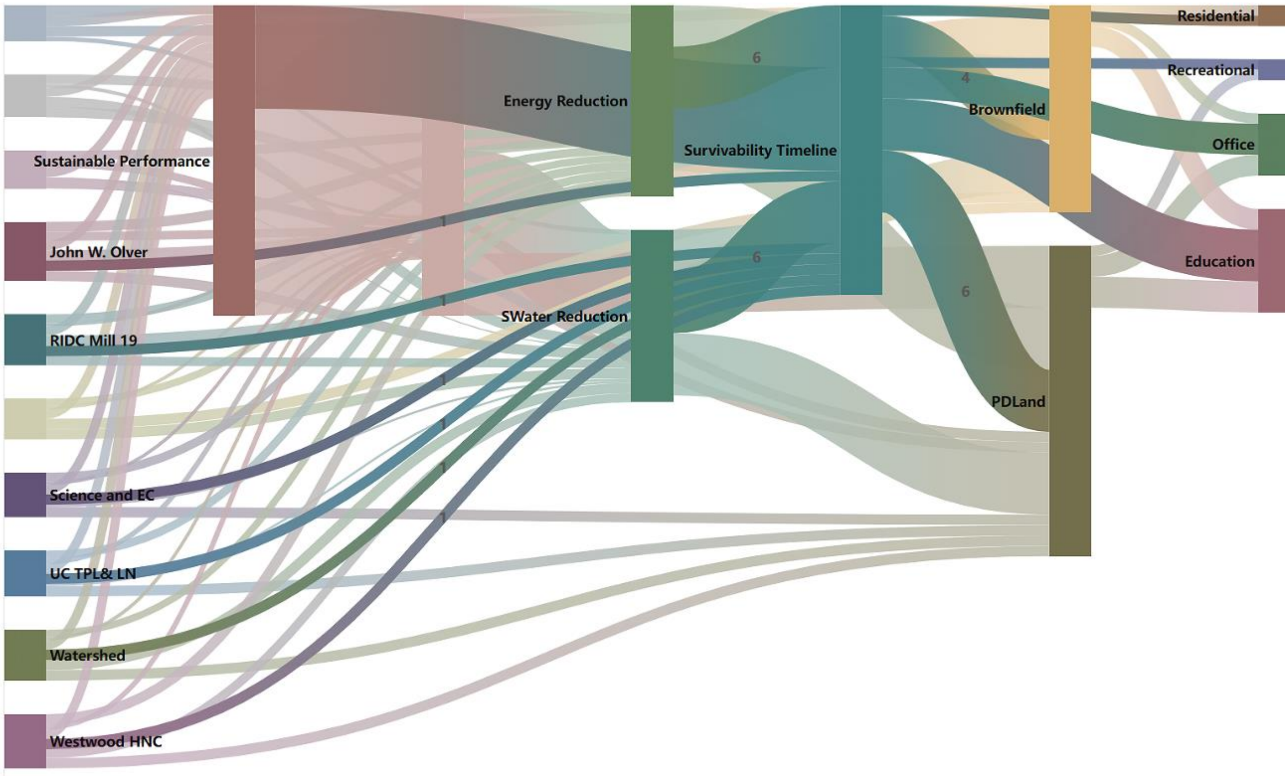

Figure 6. Sankey diagram highlighting survivability timeline in relation to design aspects

On the other hand, Figure 5 highlights the visible connections between design aspects (defined in section3 of this paper) and water resource reduction. It reflects that four selected projects have reduced stormwater runoff by 100%. These projects include Confluence Park, John W. Olver Transit Center, Harvard University Science and Engineering Complex, and the Watershed Building. The other six projects achieved runoff reductions between 86.8% and 11.8% (represented as 0.86 and 0.11 in Figure 5). This analysis indicates that the number of projects achieving a 100% reduction in energy consumption is less than the number of projects achieving a 100% reduction in stormwater runoff. This underlines the efforts underway to prioritize applications of water sustainability in design. It indicates the complexity of water sustainability in design, particularly in North America. These projects have shown that although there is potential for 100% runoff reduction, there are many other factors that contribute to water sustainability in design. This includes energy efficiency, habitat restoration, and green infrastructure, all of which must be considered.

To address design for change, this paper explores how a futuristic vision is incorporated into the evaluated projects. This includes evaluating the critical infrastructure included in the design of the selected projects. This infrastructure supports events such as pandemics, natural disasters, wildfires, and floods. It is interesting to note that each of the selected projects employs a wide range of design approaches to address adaptability. For example, the residential project Casa Adelante 2060 Folsom served as a safe sanctuary for its occupants during the pandemic. Confluence Park is designed to operate passively through disruptions to energy and water resources. When there is a crisis, the DPR Sacramento Zero Net Energy Office can serve as a safe harbour for the community. It also has a seed bank to propagate reforestation following wildfires and a battery backup system to maintain operation in the event of a flood. Harvard University Science and Engineering Complex has robust floodproofing, passive-design measures, and backup generation designed to withstand extreme events. For the John W. Olver Transit Center survivability is estimated at between 12 and 30 hours depending on the season and the nature of an event or catastrophe [5]. The project RIDC Mill 19 Buildings A & B can function for 24 hours in crisis through passive sustainability [6]. On the other hand, the Science and Environmental Center demonstrates how human interventions can be sensitive to the local environment and support regional ecologies [7]. By virtue of its design it offers passive survivability and is limited to offer 24 hours support. UC San Diego North Torrey Pines Living & Learning Neighbourhood would act as a safe harbour for its more than "2,000 residents" during a crisis for 8760 hours [8]. This project also provides year-round passive survivability using injected renewable energy sources. Whereas, the Watershed building and the Westwood Hills Nature Center, both are designed for passive sustainability to survive 72 hours [9]. Passive survivability is defined as "a building's ability to maintain livable conditions [when critical life-supporting] sources such as electricity, water or heating fuel are cut off' [10]. Based on this analysis, it was found that most of the selected projects have not only calculated survival timelines to accommodate users during crisis events and assist recovery from natural disasters but have also tested and verified these timelines based on project performance and occupant satisfaction data measured over 12-month period. This measurement is a required qualifying criterion for projects considered under COTE's top ten awards. The results of this analysis reveal that these projects have been successful in providing occupant safety during crisis events, as well as assisting with recovery from natural disasters. The success of these projects demonstrates their value in providing real-world solutions to crisis and disaster management.

5. Analysis

Based on the above investigation, it is identified that these projects can offer crisis support using sustainability design measures included in their design themes. These measures create resources for use during crisis events. As a result, backup generation methods, integration of renewable energy sources and stormwater catchment strategies are included as part of the project's initial design intent rather than being an additional add-on to the project. These strategies not only help in resource reductions but also enable these projects to operate independently without reliance on city-connected infrastructure, which becomes critical for survival during a crisis event. This establishes the fact that projects following a sustainable design theme can easily incorporate critical infrastructure to support design for change. It is also observed that six out of the ten projects claim a defined survival timeline as represented in the Sankey diagram Figure 6. Figure 6 indicates that these claims of defined survival timeline are achieved by projects achieving 100% (represented as value 1 in the Sankey diagram) reductions in energy and water use. The survival timelines identified during the investigations demonstrate the effectiveness of the selected projects in helping people survive disasters. In addition, they demonstrate their potential to become a model for future projects. The data collected from the projects can be used to inform future design decisions and create buildings better prepared for crisis events. This data is also indicative of the design strategies implemented to offer support during and after a crisis event. For example, at the DPR Sacramento Zero Net Energy office, a solar battery backup system is part of its design to maintain operation in the event of a flood. In addition, there is a seed bank designed to propagate reforestation following a wildfire event. It is important to adopt such strategies to prepare for floods and wildfires that are becoming more frequent as climate change progresses. These strategies are useful considering wildfires in California this year have caused devastation of over 4 million acres of land, and the floods in the Midwest have caused more than $3 billion in damages. This analysis provides evidence that such projects are successful in addressing the needs of the community and creating lasting impacts that help address design needs to respond to climate change, and support resilient recovery from disasters.

Specifically, in view of the changing climate causing increased natural disaster frequency and intensity such as floods, wildfires, and hurricanes. Building and infrastructure designs that can withstand these events are crucial for inhabitants' safety and well-being. It is recommended that future practices incorporate similar climate-adapted designs. Because it is more efficient and economical to build resilient structures from the start than to rebuild them after a disaster. This should also include considerations for materials that can withstand extreme weather events or be easily repaired or replaced when needed. This combination of sustainable, climate-adapted and resilient architecture can help reduce overall greenhouse gas emissions and mitigate climate change by reducing energy use and water use and promoting sustainable practices. Incorporating this combination into the design can also have social and economic benefits, helping communities recover quickly and reducing disruption to daily life. By doing so, a space/building/facility will become more liveable and comfortable and its users will become more confident about survival during a crisis event. This is essential for creating safe, sustainable, and functional designs that improve people's quality of life in the present and into the future. Architects can benefit from this combination by developing sustainable, resilient and adaptive structures to the environment and climate. This way, they can ensure that buildings are designed to operate efficiently and be resilient in the face of uncertainty. Furthermore, this combination approach can help architects create buildings that are not only aesthetically pleasing, but also highly functional and capable of adapting to an ever-changing environment.

6. Conclusions

On the basis of exploring how the selected projects met or exceeded sustainable design criteria, how these sustainable design criteria are achieved through resource reduction strategies defining critical infrastructure and how this critical infrastructure impacts survivability timelines as a dependent variable of resource reduction. This investigation provides insight into the visible and invisible connections that define how projects adapt to climate change and support resilient recovery from disasters. As a result, it is understood that sustainability is not just about energy efficiency, but also about equitable and socially responsible design. By understanding and addressing the social and economic impacts of climate change, sustainable design can become a tool for supporting resilience and adaptation. By embracing sustainability holistically, architects can create visually appealing, innovative and supportive building designs. The considerations given to passive design strategies like natural ventilation and daylighting to reduce energy consumption along with active design strategies like cogeneration systems, hybrid ventilation models and renewable energy sources can improve energy efficiency in design that not only impacts project cost and savings but also impacts survivability timeline, occupants' health and well-being positively.

This paper highlights the importance of collaborative design that involves multiple stakeholders to integrate sustainable design for a low carbon future. This understanding extends beyond the traditional norms of designing buildings around nature to serve as a model for sustainable development. This is where the integration of sustainable materials and renewable energy minimizes carbon footprints and associated environmental impacts. Additionally, these projects showcase an innovative and futuristic vision where the design community is consciously addressing the needs in their design to adapt to a changing climate and support resilient recovery from disasters, which goes beyond conventional sustainability measures. Furthermore, it is also understood that the new generation of design prioritizes educational awareness among occupants and the public. This is to promote environmentally friendly design methods, support awareness and increase adoption among project occupants. This is essentially understood from Figure 2, which shows half of the selected projects evaluated in this paper as educational facilities engaging a wider community and offering better survivability timelines. These educational projects are designed in a way that is focused on creating a better environment for learning, collaboration, knowledge dissipation and social interaction. The other half of the selected projects are office, residential and recreational projects. These include combination design applications at the scale of a neighbourhood, and urban park prioritizing sustainability, liveability, functionality and community engagement to support climate change adaptation.

Declarations

The authors have no competing interests to declare that are relevant to the content of this article. Data used is available through references cited in this paper. The responsibility for the content and any remaining errors remains exclusively with the author.

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