A review of recent proposals for addressing climate change impact in the construction industry

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Abstract
Proposals for addressing the problem of climate change have been put forward since the 1970s when the issue of the ozone layer depletion became an object of concern. Within the construction industry, research has been going on to see how best to manage the effects of climate change within its own limits. While the concept of changing climate is a natural phenomenon, the accelerated changes that have been witnessed world-wide within the last century can only be blamed on human activity. While it is desirable to curb human activities that are protracting the issue, developing proposals to manage the effects of climate change on the environment has become crucial. This review set out to examine the measures being proposed in recent years for the construction industry with a view to determining which set of ideas are receiving more support for application in the immediate present and the future. The investigation was carried out by sourcing articles from Web of Science that covered the climate change topic for the construction industry between 2009 and 2023. The materials were screened to thirty most relevant articles to extract the proposals for thorough investigation. The research discovered that proposals were centred on energy conservation, emission reduction and structural evolution. It was concluded that despite more publications reporting on some proposals, no position is superior. The study proposes that efforts should be made to emphasise and promote the adoption of adaptation measures and integrated design approach in developing countries while finding ways to improve implementation.

Keywords: adaptation, emission reduction, energy conservation, integrated approach, mitigation, structural evolution

1. Introduction

Discussions about curbing the effects of climate change have been dominated by expositions on adaptation and mitigation proposals. There is however a school of thought that proposes that both measures are more or less of the same essence and there is no difference between them (Barlow *et al*. 2018) [8]. There have been several investigations on the activities in different fields of endeavour to evaluate their proactivity towards environmental sustainability within the ambit of climate change. Mitigating the effects of climate change is essential to lower the existing and projected impacts on the built environment whereas, adaptive measures tend to explore the coping mechanisms or inbuilt resilience of the environment to the effects of climate change. While mitigation requires conscious measures with higher cost implications that are directed at the causative factors in climate change and more intrusive, adaptive measures are necessary especially in the developing world with their high vulnerability especially in their infrastructure (Andrić *et al*., 2019; Tran, Hall, Nicholls, Hickford, Chaudry & Watson, 2018; Intergovernmental Panel on Climate Change, 2014) [5, 44, 23]. The adopted options for different parts of the world are thus influenced by the conditions of the built infrastructure on ground and the outlook of the economy. Some aspects of buildings and other infrastructure are designed to last for their entire lifecycle. These items include the structural frames like foundations and columns, the envelope like the walls and the roofs. Components such as the glazing, other finishes and building services are expected to be maintained or sometimes changed from time to time (Edwards, 2014; Gething & Puckett, 2013) [16, 20]. All these features are expected to be considered and addressed at the design stage and life cycle planning of structures and matched with required climatic response. There should also be due considerations of the climatic thresholds beyond a structure's factor of safety. The vulnerability of the occupants also depends on the structures and the nature of climatic changes that are being experienced in the area (Roaf *et al*. 2009) [41]. This position calls for the necessity to erect infrastructure that can withstand the effects of climate change which is an adaptive solution (Edwards, 2014) [16]. The construction industry contributes about 30% to global greenhouse emissions (Zhai & Helman, 2019) [48]. Buildings are also reported to consume 40% of global energy demand (Intergovernmental Panel on Climate Change, 2007) [22]. Of importance is to promote environmental responsibility through developments and proposals that can avert environmental degradation through human activities and habitation. This position leads back to sustainable development which ensures the responsible use of resources in a manner that generates less waste while enhancing optimal performance (Edwards, 2014) [16]. The adaptation and mitigation measures that are intended as responses at any point must align with sustainable development goals.

2. Adaptation measures

Climate change is characterised by marked alterations in average weather conditions that have become permanent (Liu and Cui, 2018) [28]. While climate change is accepted as a natural phenomenon, the implications on the built environment culminating in social and economic challenges become noticeable due to shifts in the severity and frequency of extreme weather conditions (Hernández, 2022) [21]. The presence of greenhouse gasses in the atmosphere is one of the major contributors to the extreme weather conditions being witnessed all over the world. The rate of reduction in the concentration of greenhouse gasses is not currently at the levels required to mitigate the climatic hazards it is causing (Eriksen *et al*., 2011) [17]. Ajala (2019) [2] had proposed that adaptation measures should be the primary response of developing countries who contribute so little to the causes of climate change through greenhouse gasses but are very vulnerable to the impacts. Adaptation measures are defined as developments that enhance resilience and reduce vulnerability (Watts *et al*. 2015) [46]. They enhance the capacity of a system to absorb distortions and revert to equilibrium position in order to retain identity, function, structure, and feedbacks. Adaptation as a response to extreme weather conditions comes in many ramifications. The proponents of adaptation measures have discussed creative adaptation (Edwards, 2014) [16], sustainable adaptation (Eriksen *et al*., 2011) [17] and so many other types. Adaptation could also be looked at from the points of (i) private and public, (ii) anticipatory and reactive and (iii) autonomous and programmed (Bodale, Catalina and Ionuț 2019) [10]. The effectiveness of any of these positions is dependent on the alteration of user behavioural patterns and the rate of global warming (Zoumakis, Zoumakis, & Prevezanos, 2017) [50]. There are however, two distinct forms of design adaptation that have been established in the built environment; *behavioural adaptation* and *structural adaptation*. A third concept in design adaptation that is recently gaining mention in the adaptation discourse is *resiliency*.

It is estimated that construction activities in developing countries will be doubled in urban areas by 2030 offering a large potential to institute adaptation planning into future structures (Bai *et al*., 2018; Intergovernmental Panel on Climate Change, 2014) [7, 23]. Effective adaptation goes through three stages which include (1) recognising threat, (2) choosing to act, then (3) executing action (McGregor *et al*., 2013) [30]. The Intergovernmental Panel on Climate Change (2014) [23] insists that climatic integration is the first step towards adaptation, thus reducing the vulnerability to existing weather extremes. The ability to adapt to weather extremes is informed by the passive and active building components that control climate. Spaces, organisations, assembly patterns and materials used in construction are all parts the components being referred to. The general position among the proponents of adaptive measures is that adaptation has a greater and longer lasting potential than mitigation.

2.1 Structural adaptation

The ability of a structure to retain its safety factor within the accepted specified limits after an extreme climatic event or weather disturbances is referred to as structural adaptation (Owen, 2020) [34]. The structural integrity, stability and rigidity of the structure with regards to its equilibrium state should not be overtly compromised. It is a passive control attribute of buildings and civil engineering structures within the concept of adaptive response to extreme weather impact. This concept is a direct responsibility of the physical aspects of the structures to transfer loads and resist shear forces and vibrations that may otherwise cause it to deflect of fail structurally due to the effects of the extreme weather conditions. Within the concept of structural adaptation, there is room for flexibility which deals with the adjustment of spatial layout and adaptation of building systems which deals with the design and construction of building services within the structures (Osman and Sevinc, 2019) [33]. To make a structure structurally adaptive to climate change, load bearing elements like; retaining walls; foundations; beams and columns, building services, internal partitions and space enclosures must be properly designed and constructed in proper synergy to resist the impacts of anticipated extreme weather conditions. The building envelope is not excluded from the responsibility to address climate change impact in adaptive response (Piselli *et al,* 2020) [37]. It comes in very useful in addressing passive temperature controls and building energy needs through cutting-edge technologies that are being developed globally. Traditional construction methods if well utilised are also very effective in addressing extreme weather conditions. Indigenes of Solomon Islands in the Oceania use elevated floors to combat flooding that occurs annually during the monsoon season and construct aerodynamic houses with sago palm leaves for roofing to reduce the wind shear on their buildings (Boyle, 2013) [11].

2.2 Behavioural adaptation

While structural adaptation focuses on stability issues in structures during climatic disturbances, behavioural adaptation is more concerned on the para-physical responses, activities and characteristic adjustments of structures which may impact on occupants and users during and beyond environmental disturbances. It also covers the aspect of human behaviour and relationship with the environment in the management of extreme weather conditions and its concomitants. Occasional flooding and heat waves could require some simple behavioural adjustment to cope with the conditions. While designing buildings, the operations and systems within structures can be made flexible to accommodate foreseeable changes in the environmental conditions and user's requirements. Behavioural adaptations can only suffice for extreme disturbances that don't seriously affect the structural stabilities of structures or those that have very low probability of occurrence. Watts *et al*. (2015) [46] referred to such occurrences as "tail risks". The use of interactive façade with operable windows, solar shades, adjustable blinds and shutters to actively deal with temperature, light and air variations for human comfort is an expression of behavioural adaptation. It is estimated that energy demands in developed countries can be reduced by 20% in the short term and up to 50% of present levels by 2030 if the necessary lifestyle and behavioural changes are institutionalised (Intergovernmental Panel on

Climate Change, 2014) [23]. Several studies have shown that human behaviour is explicitly responsible for the attainment of the most promising adaptive measures ever proposed which makes it expedient to factor in the aspect of human behaviour and their limitations at the design stage in achieving the desired goals (Ezeabasili & Okonkwo, 2013; Coley *et al*., 2012; Akande & Adebamowo, 2010) [18, 14, 3]. There are however some observed limitations to the concept of behavioural adaptation. Murtagh, Gatersleben and Fife-Schaw (2019) [31] identified the influence of coping mechanisms through lifestyle changes has stronger influences on residents to accept adaptive responses than the perception of their inherent vulnerability to excessive heat which should have motivated them to take action. There are also established climatic thresholds beyond which built structures are unable to provide safe occupancy for occupants and users (Roaf *et al*., 2009) [41]. In such instances, the vulnerability of the occupants and users is dependent on the resilience of the structure to withstand the extreme weather conditions through its fabric and form to a very large extent.

2.3 Resiliency

Disaster/climate resilience is one of the factors influencing how buildings will develop in the future (Clements-croome, 2018) [13]. A proactive adaptation technique focused on sustainability is resilience. It guarantees that structures or systems can survive environmental risks without significantly compromising their safety or functional suitability. Resilience has been characterized by several disciplines using various notions (Ribeiro & Gonçalves, 2019) [40]. Rajkovich and Okour (2019) [38] defined resilience as the process of quantifying the possibility of a hazardous event on a community with their internal and external vulnerabilities and their propensity to recover physically, economically, and socially after a disturbance. This definition takes disaster risk reduction into consideration. In other words, it is the capacity to foresee, make accommodations for, and adapt to threats. Buildings resilience focuses on overcoming sensitivity to the consequences of climate change, as opposed to "green building" and climate-responsive designs, which deal with sustainability (Watson & Adams, 2011) [45]. According to the Federal Ministry of Power, Works, and Housing (2016), it is the ability of a structure or system to flourish in the midst of stressors. While "green building" and climate-responsive designs are concerned with sustainability, building resilience is concerned with reducing vulnerability to the consequences of climate change (Watson & Adams, 2011) [45]. Lerch (2017) [27] clarified, however, that robust buildings on their own don't always imply a resilient community. A population group may not be able to use a high-performing building due to additional costs, or there may not be money left over to pay for other essential facilities. When each building unit increases the community's ability for adaptation, resilience as a system is attained (Lerch, 2017; Rajkovich & Okour, 2019) [27, 38]. According to Rajkovich and Okour (2019) [38], resilience in the built environment should go beyond recovery and bouncing back to the status quo to an enhanced adjustment to risks against repeat recurrence. Built environment professionals should take this approach into account when drafting a resolution to rethink potential solutions to the climate change problem.

3. Mitigation

Mitigation is the process of lowering atmospheric pollutants that contribute to climate change. It came about as a result of worries about the future of energy security and a warming world. They tend to favour climate-responsive design, which guards against potential environmental damage caused by human occupation and activity (Williamson *et al*., 2003) [47]. In contrast to adaptation strategies, mitigation techniques aim to obliterate the root of the problem. As a result, it is a successful step toward long-term resilience across all industries. According to McGregor and Roberts and Cousins (2013) [30], "the degree of mitigation will set the course for the degree of adaptation." This measure is adopted by the United Nations Development Program (UNDP) in energy load reduction through efficiency, embodied energy reduction and strategic leadership for climate change (McGregor *et al*., 2013) [30]. The most widely accepted definition of sustainable development states that it must meet present needs "without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987, cited in Edwards, 2014) [16]. It is generally observed that policies and actions on sustainability are focused on mitigation (Röck *et al*., 2020). Findings from past studies reveal that the construction industry has the greatest potential for cost-effective mitigation thanks to the utilization of modern building designs, technology, and regulations (Andri *et al*., 2019; Ba & Galik, 2019; Dean *et al*., 2016) [5]. Clements-Croome (2018) [13] and Kibert (2013) posit that the built environment is to blame for 50% of energy consumption, with repercussions of building energy demand accounting for 45% of operational energy and 5% of construction energy. Filippn, Larsen, and Ricard (2018) found that embodied energy accounted for 16% of total energy consumption in their research of home construction in Argentina, while operational energy accounted for 84%. The operational energy needs of buildings are a function of temperature, building design, location, and user behaviour, however embodied energy could be evaluated through life-cycle assessment (Creutzig *et al*., 2016). The main objective of mitigation is to lessen the extent of this consumption. Lighting, Heat Ventilation and air conditioning (HVAC), domestic hot water, kitchen appliances, and water pumping are energy end-uses that are seen in homes. Grid electricity and fossil fuel driven generators are the main energy sources for these operations (Ezema, 2015). Climate-responsive architecture thus consists of deliberate designs that aim to balance or reduce architectural expressionism with an improved or upgraded energy performance of a building (Farrelly, 2018). The most mentioned concepts in the mitigation discourse are; *low energy, low carbon, integrated design, green design* and *life cycle assessment.*

3.1 Low energy movement

The quest of sustainable development has significant challenges related to energy conservation (Edwards, 2014) [16].

Because many modern structures were created at a time when the science of climate change was not fully understood, fossil fuels have been the traditional source of energy for more than a century. Dependence on fossil fuels led to an increase in GHG emissions, primarily CO2, making it unsustainable. The underlying premise is to use renewable energy sources to balance off other energy demands and lessen reliance on fossil fuel energy while maintaining user comfort levels that are appropriate. This trend seeks to reduce the need for HVAC systems and artificial lighting through design suggestions. Utilizing electrical equipment with minimal energy requirements is also necessary for optimal performance. The low-energy design process was divided into four categories by Keeler and Vaidya (2016): design to reduce electric loads, design efficient systems to manage residual loads, design renewable energy systems, and design efficient building operations. According to the reasoning, using less energy to complete the same tasks reduces GHG emissions, conserves resources, and lowers consumers' energy expenditures, expanding the pool of people who may benefit from energy (Filippn *et al*., 2018). Net-zero energy or energy-neutral buildings have annual energy generation that balances their demands. Zero-energy designs, which are totally self-sufficient without the need of fossil fuels, are another variation on this concept (Looman, 2017; Keeler & Vaidya, 2016). Energy plus designs, which create excess energy and store it or transmit it to a central grid system to lessen the strain on other buildings, are a higher grade of energy movement. Energy surplus systems are best used in mixed-use projects, according to Keeler and Vaidya (2016), who stated that they are of limited utility if they are installed on the scale of a single building.

3.2 Low carbon movement

In order to assess negative impact, carbon measurement employs CO2 generation or emission as a normative criterion rather than energy use. They evaluate how operational and embodied carbon impact building. According to Appleby (2011) and Ezem (2015), the amount of fossil fuel energy utilized directly correlates to the amount of CO2 created. Therefore, zero carbon implies that no fossil energy was used, which means that all of the building's energy needs were met by renewable resources. There are other buildings that are carbon-neutral; these structures become net-zero producers by minimizing the amount of operating energy needed to compensate for their embodied carbon (Looman, 2017). According to research by Dean *et al*. (2016) [5] and Bai *et al*. (2018) [7], building infrastructure for rapidly expanding cities, particularly those in developing nations, could result in the release of 226 gigatonnes (Gt) of CO2 by the year 2050, which is four times the amount required for infrastructure in the developed world today. According to the study, cities need "low-carbon construction, alternative transport, and better [built environment] planning and design" in order to reduce emissions (Bai *et al*., 2018, p. 25) [7].

3.3 Integrated design approach

The first two measures mentioned used a reductionist approach, where the problems are broken down to find the key element in creating an efficient solution. These response measures, in the views of Xu, Wang, Liu, He, Tanga, Nguyen, and Cui (2019), Liu and Cui (2018) [28], and Ürge-vorsatz *et al*. (2018) [7], could also constrain one another, especially in the case of unilateral adoption of each strategy, resulting in trade-offs between the two measures. The overall design response to climate change is treated as a linked structure in which a pull in one area impacts other sections, according to the Integrated Design Approach (IDA), which employs a systems approach (Kibert, 2013). Tompkins and Adger (2005) [43] noted that studies in numerous sectors on how to respond to climate change aimed to integrate the cause and effect of development processes in order to offer strategies for a comprehensive response.

This strategy lessens the financial impacts of sustainable designs while also exposing building sector designers to a wider range of impacts, including final energy use, aesthetics, building operations, and occupant experience (Federal Ministry of Power Works and Housing, 2016; Keeler & Vaidya, 2016). According to research by Urge-Vorsatz *et al*. (2018) [7] and McGregor *et al*. (2013) [30], minimizing UHI through adaptation-using landscape design-also reduces the GHG emissions from air conditioning. According to Garshasbi *et al*. (2020) [19], IDA can cut the amount of future cooling energy needed for typical residential buildings by 70%. IDA was described as the procedure by Keeler and Vaidya (2016, p. 125) where "design decisions made earlier in the design process do not compromise the effectiveness of design decisions that need to be made later." According to Williamson *et al*. (2003), p. 14 [47], "creative adaptation to ecological, sociocultural, and built contexts" is taken into account in a sustainable response. According to Eriksen *et al*. (2011) [17], sustainable adaptation should emphasize low-emission solutions as a kind of mitigation. This suggests a combination of the earlier mentioned strategies of adaptation and mitigation. However, Kim and Grafakos (2019) [25] pointed out that if adaptation and mitigation actions are not effectively coordinated, combining them may have the opposite effect. Therefore, technical expertise is required for a successful integration of these design measures. There are many IDA-related fields, but given the breadth of this study, we focused on issues of resource usage and building design in response to climate change.

3.4 Green design movement

The paradigm for architecture in the twenty-first century is green design, or "green building" (Edwards, 2014) [16]. It is the moral response to historical worries about the environment and resources. Although there are many definitions of "green building," Keeler and Vaidya (2016) argued that the overarching theme must address multiple environmental issues (such as natural depletion, carbon emissions, or waste). In addition to providing a healthy indoor environment, it should address site demolition difficulties, work toward resource efficiency, conserve or enhance mechanical energy efficiency, and so forth (Cairns Regional Council, 2011; Bauer *et al*.,

2010) [12, 9]. The cornerstone of green design is the sustainable use of resources and materials. As a result, they are structures that use resources more effectively while minimizing the negative effects of building construction or operation on human health and the environment through site selection, design, construction, operation, maintenance, and demolition. Additionally, because they solve the performance shortcomings of conventional buildings in terms of energy use and occupant health (Darko *et al*., 2017; Appleby, 2011) [15], green buildings have greater economic benefits across their whole lifecycle. Buildings have an impact on how we feel, think, and behave (Keeler & Vaidya, 2016; Roaf *et al*., 2009) [, 41]. This suggests that there are numerous aspects that may be taken into account at the design stage that have a substantial impact on building occupants, particularly with relation to building services. Compared to traditional buildings, occupants in those built with the environment in mind were more productive and took fewer sick days.

The term "life-cycle assessment," or LCA, refers to the process of evaluating the resources used from the production of materials until their final disposal. It takes into account all the implications of the material selection decision rather than its performance in order to deliver superior design insights and value judgments regarding resources for the construction (Kibert, 2013). The cost of resources (electricity) and materials (bricks) is compared to environmental standards through LCA. Oyediran (2019) asserted that it would be difficult to address environmental sustainability in areas where building costs are high since Kibert (2013) found that 20% of the energy used during the lifecycle is used in the production of building materials and construction. Environmental certification is not a guarantee of high-quality architecture, according to Edwards (2014, p. 99) [16]. In their 2020 paper, Loh, Foth, Caldwell, Garcia-Hansen, and Thomson questioned the usefulness of energy efficiency as a performance criterion for sustainability in green rating tools. The study also found that while the weights of the assessment criteria vary, compliance with one rating instrument does not ensure compliance with the others.

3.5 Life-cycle assessment

The process of assessing the resources used from the creation of materials through their ultimate disposal is known as life-cycle assessment, or LCA. To provide better design insights and value judgments regarding resources for the building, it considers all the side effects of material selection decision rather than its performance (Kibert, 2013). LCA compares environmental criteria to the cost of resources (energy) and materials (bricks). Oyediran (2019) argued that it would be challenging to address environmental sustainability where the cost of construction is high because Kibert (2013) revealed that energy invested in building materials and construction accounts for 20% of the total lifecycle energy. LCA advocates a quick evaluation of energy plans and the use of recyclable materials, which means changing the paradigm from "cradle to grave" thinking to "cradle to cradle" application from the beginning. The four stages of a project's existence are covered by this analysis: design, construction, use and maintenance, and deconstruction. Therefore, a paradigm shift in how the earth's natural resources are used is necessary to respond to climate change. It was essential to carefully evaluate building components and energy selection that would remain healthy and conservative over the building usage life due to the decadal lifetime requirements for the built environment (Edwards, 2014) [16]. The ability of a material to be recycled at the end of a building's life is emphasized by LCA. The manufactured risk is reduced by a factor of one when resources are reused. Materials are the primary factor in embedded energy, hence greater durability indicates lower recurrent embodied energy. The difficulty, however, goes beyond suggesting or designing novel materials to endure 'tail risks' in a short amount of time; it also involves developing materials that maintain their core strength and flexibility in a variety of uses, even longer than the lifespan of a building. As a result, LCA functions as a comprehensive tool that connects design services, manufacturing, construction, building maintenance, and building deconstruction (Edwards, 2014) [16].

4. Discussion

There are three major stages in the construction industry that can affect the environment in the short term and the long term; the design stage; construction stage and building use stage. The building environment professionals are directly responsible for actions and decisions that emanate from the three stages. While users can also contribute to the outcomes of the stages as they affect the environment, the professionals ultimately have the controls in every stage. More building industry professionals are involved in the design and construction stages while their activities impact a lot on the occupants, equipment and running of the structures in the building use stage. The design stage however is the most relevant while addressing the climate change issue though building professionals are yet to fully explore this aspect of climate change response (Akinola *et al*., 2020) [4]. The study set out to identify the more recent paradigms in the question of climate change response within the building industry. The limits set for the study are indicated within the ambits of the activities of the building industry professionals and their influences on the activities of and decisions of others outside the industry. In the course of the investigation, three major clusters of proposals were identified in a broad overview; the energy conservation proponents; the emission reduction proponents; and the structural evolution proponents. While energy conservation and emission reduction align with the mitigation agenda to reduce the human component of the fuelling of global warming, structural evolution deals more with adaptation to the outcomes of the climate change problem.

The cluster of proposals that deal with energy conservation by the construction industry professionals are more inclined to dealing with sustainability and conservation in the first instance. The climate change subject though linked to these articles are incidental concomitants in the presentations. Conserving energy during the design process has not been considered as a priority since the input is mostly from mental activities. Energy conservation during construction activities is addressed in major projects to save costs and manage resources. There are however some concomitants of climate change response especially where it connects directly to release of particles, gasses and other matter into the environment that can an impact negatively on global warming. The construction sector is a principal consumer of global energy, and materials (Zhang, Yan, Hu & Guo, 2019). The sector's activities also result in the generation of very large quantities of waste materials and pollutants that cause a large quantum of emissions and greenhouse gasses (Pervez, Ali & Petrillo, 2021). These environmental impacts are of great concern because the climate change risks associated with them can snowball into environmental costs equivalent to 5% of the annual global GDP (Kristl, Senior & Temeljotov Salaj, 2020).

Energy conservation during the stage of building use to address climate change also stems from the conservationists' proposals as an eventual concomitant in the observation of the tenets of the green designs as proposed by Green Building certifications such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method).

The proponents of emission reduction to tackle the issue of climate change in the construction industry are only able to address the issue within the construction processes. The concept which proposes the limitation of combustive and greenhouse gases only look at the construction industry as a minor contributor in the processes but fingers the built environment as a major contributor to the emissions.

Structural evolution is achieved by adapting buildings and other civil engineering structures to cope with the effects of climate change. This level of response which forms the crux of construction industry approach to the climate change problem is more popular among the publications domiciled in the developing countries. The cost and technology required to reduce the causal factors that fuel climate change are not easily assessable to these economies.

A limited impact factor was calculated for each of the three proposals. Impact factor for journals is usually calculated from the number of citations of the journal by authors over a two-year period with reference to the available number of journals that can be cited (Ioannidis *et al*, 2019). The impact factor for the proposals was calculated by summing up the number of citations of the articles where each of the proposal were advocated and dividing by the total number of articles that were selected for the investigation. The findings are presented in the table 1. There were thirty major articles investigated and many of them advocated more than one of the three proposals. This is a source of overlap in the numbers of citations that are counted for the proposals. While the impact rating derived is not judgmental on the efficacy of any proposal with respect to the lot, it gives an insight of authors' preferences on solutions to the climate change problem in the construction industry.

Table 1: Weighted impact ratings for climate change proposals in the study

S/N	Proposal	Mentions	Major citations	Weighted Impact rating
1.	Energy conservation	39	Darko *et al*., (2017) [15]; Appleby, (2011); Bauer *et al*., (2010) [9]	1.33
2.	Emission reduction	34	Dean *et al*. (2016) [5]; Bai *et al*. (2018) [7]; Looman, (2017).	1.13
3.	Structural evolution	11	Boyle, (2013) [11]; Piselli *et al*., (2020) [37]	0.37

While energy conservation and emission reduction cut across most fields of endeavour in science and humanities, structural evolution is more directed at the building industry, especially their products. Fewer mentions of structural evolution in the discourse of climate change responses are thus expected. The building industry professionals who are saddled with the responsibility of implementing structural evolution can only act where there is willingness to carry out such measures. According to Tompkins and Adger (2005) [43], the same factors that increase society's willingness to respond, such as attitudes toward risk and uncertainty, access to capital, the vulnerability context, and the institutional context, also influence adoption of new technologies or climate-responsive innovations. Akinola *et al*. (2020) [4] noticed that many of the tactics building industry professionals were aware of have yet to be widely implemented. Abdu and Jibir (2018) [1] discovered that, in general, business kind or establishment structure has a favorable influence on strategy adoption; additionally, firm age, location, and greatest educational qualification of respondents influenced their inclination to be innovative. Affiliation with certain professional groups was also required for the implementation of certain design methods, including effective fenestration and flood control, flood and wind adaptability, and building envelope for passive lighting. This was also observed in Latin American countries, where Kim and Grafakos (2019) [25] discovered that membership in regional institutions and associations contributed significantly to the integration of mitigation and adaptation strategies in cities. This suggests that institutional teaching or intervention may have had a significant influence in promoting the highlighted techniques. According to Ochedi and Taki (2022) [32], climate change response initiatives should not simply focus on the technical aspects of adoption; the social, environmental, and organizational contexts, or preparedness, are critical backdrops for the effective adoption of selected design concepts.

From the impact ratings calculated above it is obvious that there is more tendency to address the issue of climate change responses from the points of emission reduction and energy conservation which align more with mitigation. The construction industry needs to showcase its efforts which are more visible in the structural evolution for better reporting.

5. Conclusion

NASA recently clocked July 2023 as "hottest month on record ever since 1880". Fuelled by bush fires in the northern hemisphere and Australia, the El Niño effect and increased emissions of greenhouse gasses, this trend is not showing any signs of abating. The range of proposals and classifications of approaches identified in the study have shown the trend of reportage and alignment of different schools of thought on the subject. The findings of the study do not indicate any line of thought as superior but each school of thought needs to move forward to the point of proposing implementation possibilities and identifying drawbacks that can affect implementation in different parts of the world especially in the developing countries.

References

1. Abdu M, Jibir A. Determinants of firms innovation in Nigeria. Kasetsart Journal of Social Sciences. 2018;39(3):448-456. https://doi.org/10.1016/j.kjss.2017.07.006
2. Ajala OA. Vulnerability and Adaptation to Climate Change: Key Strategies for Nigeria. International Journal of Agriculture, Environment and Biotechnology. 2019;12(2):101-106. https://doi.org/10.30954/0974-1712.06.2019.4
3. Akande OK, Adebamowo MA. Indoor thermal comfort for residential buildings in hot-dry climate of Nigeria. Proceedings of Conference: Adapting to Change: New Thinking on Comfort, Windsor. 2010;2010:1-11.
4. Akinola AO, Opoko AP, Ibem EO, Okagbue HI, Afolabi AO. Climate Change Adaptation and Mitigation Strategies in Lagos, Nigeria: Built Environment Professionals' Perspective. International Journal of Engineering and Advanced Technology. 2020;9(3):1273-1282. https://doi.org/10.35940/ijeat.B2630.029320
5. Andrić I, Koc M, Al-Ghamdi SG. A review of climate change implications for built environment: Impacts, mitigation measures and associated challenges in developed and developing countries. Journal of Cleaner Production. 2019;211:83-102. https://doi.org/10.1016/j.jclepro.2018.11.128
6. Aysha S, Mani M. Adaptation of Buildings to Climate Change. Encyclopedia of Sustainable Technologies. 2017;2:331-349. https://doi.org/10.1016/B978-0-12-409548-9.10202-
7. Bai X, Dawson RJ, Ürge-Vorsatz D, Delgado GC, Barau AS, Dhakal S, *et al*. Six research priorities for cities and climate change. Nature. 2018;555(7694):23-25. https://doi.org/10.1038/d41586-018-02409-z
8. Barlow JF, Shao LS, Smith ST. Climate Change, Resilience and the Built Environment. In T. Dixton, J. Connaughton, and S. Green (Eds.), Sustainable Futures in the Built Environment to 2050: A foresight approach to construction and development (1st ed., pp. 27–49). John Wiley and Sons Inc, 2018.
9. Bauer M, Mösle P, Schwarz M. Green Buildings: Guidebook for sustainable architecture. Springer, 2010. https://library.uniteddiversity.coop/Ecological_Building/Green_Building-Guidebook_for_Sustainable_Architecture.pdf
10. Bodale A, Catalina T, Ionuț SC. Adaptation of buildings to climate change through bioclimatic strategies, in Romania. Proceedings of Conference: 1st The 13th REHVA HVAC World Congress CLIMA 2019, 26 – 29. 2019 May;111:1–6. https://www.researchgate.net/publication/312629237_Employee_participation_in_decision-making_in_architectural_firms
11. Boyle C. Disaster resistant construction for small dwellings in Solomon Islands. In Disasters and the Small Dwelling, 2013, p183-188.
12. Cairns Regional Council. Sustainable Tropical Building Design: Guidlines for Commercial Buildings. In Wetlands. Cairns Regional Council, 2011.
13. Clements-croome D. Editorial. Intelligent Buildings International. 2018;10(4):195-196. https://doi.org/10.1080/17508975.2018.1514214
14. Coley D, Kershaw T, Eames M. A comparison of structural and behavioural adaptations to future proofing buildings against higher temperatures. Building and Environment. 2012;55:159-166. https://doi.org/10.1016/j.buildenv.2011.12.011
15. Darko A, Zhang C, Chan APC. Drivers for green building: A review of empirical studies. Habitat International. 2017;60:34-49. https://doi.org/10.1016/j.habitatint.2016.12.007
16. Edwards B. Rough Guide to Sustainability: A Design Primer (4th edition). RIBA Publishing, 2014.
17. Eriksen S, Aldunce P, Bahinipati CS, Martins RD, Molefe JI, Nhemachena C, *et al*. When not every response to climate change is a good one: Identifying principles for sustainable adaptation. Climate and Development. 2011;3(1):7-20. https://doi.org/10.3763/cdev.2010.0060
18. Ezeabasili A, Okonkwo A. Climate Change Impacts on the Built Environment in Nigeria. INTBAU Nigeria Workshop on Buildi. 2013 June 11-13;7(4):288-303. https://doi.org/10.4314/afrrev.v7i4.18
19. Garshasbi S, Haddad S, Paolini R, Santamouris M, Papangelis G, Dandou A, *et al*. Urban mitigation and building adaptation to minimize the future cooling energy needs. Solar Energy. 2020;204:708-719. https://doi.org/10.1016/j.solener.2020.04.089
20. Gething B, Puckett K. Design for Climate Change. RIBA Publishing, 2013.
21. Hernández D. Climate Justice Starts at Home: Building Resilient Housing to Reduce Disparate Impacts from Climate Change in Residential Settings. New Frontiers of Environmental Justice. 2022;112(1):66-68. https://doi.org/10.2105/AJPH.2021.306611
22. Intergovernmental Panel on Climate Change. Change OC. World Meteorological Organization, 2007, 52. (Fourth Assessment Report AR4). https://www.ipcc.ch/report/ar4/
23. Intergovernmental Panel on Climate Change I. Climate Change: Implications for Buildings (Fifth Assessment Report, AR5), 2014. www.cisl.cam.ac.uk/ipcc
24. Ioannidis JP, Baas J, Klavans R, Boyack KW. A standardized citation metrics author database annotated for scientific field. PLoS biology, 2019, 17(8).
25. Kim H, Grafakos S. Which are the factors influencing the integration of mitigation and adaptation in climate change plans in Latin American cities? Environmental Research

Letters. 2019;14(10):1-23.
26. Kristl Ž, Senior C, Temeljotov Salaj A. Key challenges of climate change adaptation in the building sector. Urbani izziv. 2020;31(1):101-111.
27. Lerch D. Community resilience and the built environment. The Community Resilience Reader: Essential Resources for an Era of Upheaval, 2017, 293–308. https://doi.org/10.5822/978-1-61091-861-9_18
28. Liu X, Cui Q. Combining carbon mitigation and climate adaptation goals for buildings exposed to hurricane risks. Energy and Buildings. 2018;177:257-267. https://doi.org/10.1016/j.enbuild.2018.08.001
29. Loh S, Foth M, Caldwell GA, Garcia-hansen V, Thompson M. A more-than-human perspective on understanding the performance of the built environment environment. Architectural Science Review. 2020;63(3-4):372-383. https://doi.org/10.1080/00038628.2019.1708258
30. McGregor A, Roberts C, Cousins F. Two Degrees: The Built Environment and Our Changing Climate. Routledge, 2013.
31. Murtagh N, Gatersleben B, Fife-Schaw C. Occupants' motivation to protect residential building stock from climate-related overheating: A study in southern England. Journal of Cleaner Production. 2019;226:186-194. https://doi.org/10.1016/j.jclepro.2019.04.080
32. Ochedi ET, Taki A. A framework approach to the design of energy efficient residential buildings in Nigeria. Energy and Built Environment. 2022;3(3):384–397. https://doi.org/10.1016/j.enbenv.2021.07.001
33. Osman MM, Sevinc H. Adaptation of climate-responsive building design strategies and resilience to climate change in the hot/arid region of Khartoum, Sudan. Sustainable Cities and Society. 2019;47:101429.
34. Owen G. What makes climate change adaptation effective? A systematic review of the literature. Global Environmental Change. 2020;62:102071.
35. Oyediran OS. Institution and Housing Development: Mirage, Magic and Miracle of Low-Cost Housing in Nigeria. Economic and Financial Review. 2019;57(4):37–68. https://dc.cbn.gov.ng/cgi/viewcontent.cgi?article=1022and context=efr
36. Pervez H, Ali Y, Petrillo A. A quantitative assessment of greenhouse gas (GHG) emissions from conventional and modular construction: A case of developing country. Journal of Cleaner Production. 2021;294:126210.
37. Piselli C, Prabhakar M, De Gracia A, Saffari M, Pisello AL, Cabeza LF. Optimal control of natural ventilation as passive cooling strategy for improving the energy performance of building envelope with PCM integration. Renewable Energy. 2020;162:171-181.
38. Rajkovich NB, Okour Y. Climate Change Resilience Strategies for the Building Sector: Examining Existing Domains of Resilience Utilized by Design Professionals. Sustainability. 2019;11:1-15. https://doi.org/10.3390/su11102888
39. Reckien D, Salvia M, Heidrich O, Church JM, Pietrapertosa F, De Gregorio-Hurtado S, *et al*. How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. Journal of Cleaner Production. 2018;191:207-219. https://doi.org/10.1016/j.jclepro.2018.03.220
40. Ribeiro GJP, Gonçalves LAPJ. Urban resilience: A conceptual framework. 2019;50:1-11. https://doi.org/10.1016/j.scs.2019.101625
41. Roaf S, Crichton D, Nicol F. Adapting Buildings And Cities For Climate Change: A 21st Century Survival Guide (2nd ed.). Architectural Press, Elsevier Ltd, 2009.
42. Sayne A. Climate Change Adaptation and Conflict in Nigeria. The United States Institute of Peace, Special Report. 2011;274:60-63. https://doi.org/10.2307/j.ctt211qx0v.8
43. Tompkins EL, Adger NW. Defining response capacity to enhance climate change policy. Environmental Science and Policy. 2005;8(6):562-571.
44. Tran M, Hall J, Nicholls R, Hickford AJ, Chaudry M, Watson G. Sustainable Infrastructure. In T. Dixton, J. Connaughton, and S. Green (Eds.), Sustainable Futures in the Built Environment to 2050: A foresight approach to construction and development (1st ed., pp. 117–136). John Wiley and Sons Inc, 2018.
45. Watson D, Adams M. Design for flooding: Architecture, landscape, and urban design for resilience to flooding and climate change. John Wiley ans Sons Inc, 2011.
46. Watts N, Adger WN, Agnolucci P, Blackstock J, Byass P, Cai W, *et al*. Health and climate change: Policy responses to protect public health. Environnement, Risques et Sante. 2015;386:1861-1914. https://doi.org/10.1016/S0140-6736(15)60854-6
47. Williamson T, Radford A, Bennetts H. Understanding Sustainable Architecture. Spon Press (Taylor and Francis Group), 2003.
48. Zhai ZJ, Helman JM. Implications of climate changes to building energy and design. Sustainable Cities and Society. 2019;44511-519.
49. Zhang Y, Yan D, Hu S, Guo S. Modelling of energy consumption and carbon emission from the building construction sector in China, a process-based LCA approach. Energy Policy. 2019;134:110949.
50. Zoumakis M, Zoumakis N, Prevezanos M. The urban built environment and temperature-related mortality risk in a warming climate. The Lancet Planetary Health, 2017, 1(8).