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Review Article

Building Regulations Adaptation to Climate Change - A Comparative Literature Review of Selected African Countries' Building Regulations

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Abstract

Climate change and its impact on the environment have caused many countries to rethink the way buildings are constructed, as cities have been experiencing extreme weather patterns like flooding. Building Regulations (BRs) can help to make buildings adaptable to climate change. Developed countries have come up with new energy codes while in developing countries little revision has been made to the current BRs. This study compared ten (10) countries in Africa (Zambia, Kenya, South Africa, Egypt, Nigeria, Tanzania, Ethiopia, Ghana, Botswana and Seychelles) to see how their BRs have been adapted to climate change. Using a comparative qualitative analysis of buildings' structural integrity, lighting and ventilation, energy and sites, the results showed that few strategies to mitigate flooding, and high temperatures in buildings were considered. The countries where reviews were undertaken in the last 10 years (Kenya, Ghana, South Africa, Nigeria, Tanzania, Ethiopia, and Seychelles) had more consideration for sustainable strategies like solar photovoltaic panels, rainwater harvesting and use of landscape to control site temperatures. The use of compact designs, Energy efficient methods of lighting, ventilation and flood mitigation were missing in the BRs except for Seychelles. There is a gap in literature because most countries have not published their recent revisions. The current BRs address the structural soundness of buildings with no specific strategies for flood waters and excessive heat. This study is unique in that it identified shortfalls in the current BRs to mitigate climate change and specific strategies were identified that can be used to update the BRs.

Keywords

Climate Change Mitigation, Building Regulations, Resilient Structures, Mitigation, Adaptation

1. Introduction

With an astounding 37% of worldwide emissions, the building industry is one of the biggest source of greenhouse gas (GHG) emissions [1, 2]. Buildings contribute to climate change, through the emission of carbon dioxide in the structure and materials [1-3]. Mitigating global warming effect may come from having BRs that address reduction of GHG emissions from the design to completion of buildings [2]. BRs are best known for ensuring the security of structures and protecting the health and wellbeing of building occupants, but they also form an ecosystem of building policies to achieve local, national, and global targets for the reduction of GHG emissions in line with SDG 11 [5-7]. BRs

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aid in building's structural integrity, safeguarding people and property from natural hazards, and ensure the safety of installed products [4]. To promote building resilience and the continuous sustainability of the built environment, BRs must be up to date with mitigation and adaption measures to climate change on the built environment [5]. The laws must promote the construction of resilient structures and the use of materials that can withstand hash weather conditions. Although the BRs aid in the design of buildings that are robust and structurally sound under normal circumstances, the extreme weather patterns make it difficult to apply them in their current state [6].

This study is a follow up on a study undertaken by the World Bank where they had a snapshot of 48 countries in the Sub-Saharan Africa's Building Regulatory Environment. Among the 48 countries in the region, the study revealed that only four (Ghana, Rwanda, South Africa, and Uganda) have updated and reformed their building regulatory frameworks within the past decade. While 45 countries have legally adopted regulations covering planning, permitting, and building control, these documents are often fragmented and lack coordination. Additionally, only 25 countries include provisions for building design, but these guidelines are either insufficient or lack comprehensive coverage in critical areas [7]. There is a gap in literature which shows that there are few codes in BRs to mitigate the impact of climate change in developing nations compared to developed countries even though developing countries are the most affected by climate change [8].

Building Regulations and Their Adaptation to Climate Change Worldwide

Hu (2019) studied the exposure and vulnerability of 1,860 cities and urban areas to natural disasters, almost 58% were highly exposed to at least to one of the six natural hazards [9]. The study highlighted that metropolitan planners and decision-makers need to reinforce resilience and adaptation strategies to tackle the increasing impacts of natural hazards. The effect of global warming are usually very severe in poor countries, for example droughts, heatwaves, and flooding, are intensified in such countries due to poverty, inadequate development, and high dependence on natural wealth [10]. According to the World Bank report on BRs for Resilience (2010), 80% of the total life years lost in disasters came from low- and middle-income countries [7-10].

Implementation of BRs has an important role to play in disaster risk reduction as BRs direct communities on how to build structures taking care of health, safety, and high energy performance [11]. Sustainable development can be advanced by increasing the policy coherence between climate change adaptation and disaster risk reduction [12]. Successful mechanisms of risk reduction and hazards adaptation in developed countries have relied on effective and efficient BRs systems which have been incrementally improved over time [8]. The question is whether the current regulations and policies are adequate to address the challenges of climate change in the built environment?

The current approach to BRs in most developing countries is essentially a handover from the past colonial codes, without consideration of the changes that have taken place over time. This approach leads to not only a significant delay in meeting present-day building requirements but also a failure to foresee and prepare for climate change mitigation and adaptation issues [11-13].

Modern BRs in developed nations have their roots in the nineteenth century, when social changes brought on by the industrial revolution gave governments a reason to get more involved in the construction sector (BRs in England by Ash and Ash in 1899, Emden in 1885, France by Risler in 1915, the United States by Gould in 1895) [13, 14]. The International Code Council (ICC), which created the model BRs and standards that are used worldwide, has acknowledged the need to change codes and standards to consider future-focused climate risk [18-20].

Due to high urban migration, economic growth and development, energy consumption has been rising quickly in developing nations thus increasing the emission of GHGs [15]. So, the current BRs can aid in reducing energy use in buildings, particularly in developing countries with high urbanization and emerging industries, the need to control emission becomes important. Energy codes and standards like Nearly-Zero Energy Buildings (NZEB) being developed in developed countries are non-existent in developing countries [16].

2. Literature Review

The African Situation

Limited adaptation and failure to predict and respond to climate-related events contribute to the high impact of environmental disasters in Africa [17]. However, there is limited evidence on BRs' adaptability to climate change, potentially indicating a paucity of these strategies in the regulations [18]. BRs were imposed on many African nations from their colonial past and few are modified to take into account planning, zoning laws, local climate and hazard design [8]. They are similarities among the various African BRs and most emphasize safety, structural integrity and health. The BRs are usually scattered across various other legislation like the Public Health Act or Urban and Regional Planning Act. Even though there is concern that buildings in Africa become sustainable, there are very few codes that can be used to make buildings resilient. Some countries like SA have the SANS 10400-XA standard and Green Building Council of South Africa (GBRSA) which focuses on promoting energy efficiency in buildings. In Kenya their BRs have been updated from the 1968 Local Government order to the National Building Code, 2022. They were revised to promotes green building standards and certifications and include provisions for energy efficiency, water conservation, and sustainable materials [19]. In Zambia there are several acts from which

BRs byelaws are derived like the Town and Country Planning Act, the Public Health Act, and the Building Restrictions [20]. In Egypt the building laws are found in the Unified Building Law No. 119/2008 and they have developed the Green Pyramid Rating System for promoting sustainable building practices [21]. The Botswana's BRs have evolved over time to meet contemporary construction requirements, safety standards, and environmental concerns, however these are not captured in the 1981 building control regulations. Initially, the Building Control Act emphasised basic structural integrity and land usage. Over time, revisions incorporated fire safety measures, drainage systems, electrical installations, and accommodation regulations. The history of Nigerian building codes extends back to colonial times, with considerable revisions over the years. The first official building rules were issued in the late 1960s, and the National Building Code was created in the 1990s to standardise standards across the country. This study focused on the 1990 building codes. Tanzania's BRs are managed by the Urban Planning (Building) rules 2018, which establish requirements for construction, safety, and urban growth. They aim to promote orderly development and conformity with zoning laws. Ghana's construction rules are principally governed by the National construction rules of 1996 (LI 1630) and the Ghana Building Code, 2018. These regulations provide criteria for construction, safety, and urban planning to guarantee that buildings are structurally sound and environmentally friendly. The Ethiopian Building Proclamation No. 624/2009 serves as the foundation for Ethiopia's building regulations. Additionally, this study incorporates insights from the CES 164 Compulsory Ethiopian Standard of 2015 to provide a broader perspective on construction standards and compliance requirements. The Physical Planning (Building) Regulations, 2024, established under the Physical Planning Act, 2021, provide the framework for building standards in Seychelles. These regulations ensure compliance with safety, environmental sustainability, construction quality, and urban development guidelines.

Sustainability is becoming more and more important, yet many construction codes still do not provide clear criteria for renewable energy use, water conservation, or energy efficiency and this disparity impedes the creation of resilient and sustainable structures [22]. When considering energy codes and sustainable technologies they must be based on the climatic and socio-economic conditions of a country. The professionals interpreting and enforcing these buildings codes have to be conversant with the requirement in achieving best practices [23]. Adhering to sustainable building requirements can be expensive and many developing countries lack funding resulting in non-compliance [8]. In Tanzania it was found that Building Material Specifications (BMSs) are rarely followed by informal construction workers because of their incompetence, client cost-cutting strategies, improper material use, and a lack of quality inspections and control procedures [24]. Major concerns have been expressed over unauthorised development, poor drainage systems, and a lack of accessibility. In addition, there have been calls for a Building Code system to increase safety and prevent calamities such as building collapses in large cities.

African countries are incorporating international climate frameworks and measurements in their development strategies, governance structures, and local development initiatives [25, 29, 27], however this is not translated in the BRs. Some policy directions include boosting ecosystems' and infrastructure's resilience to climate change [23] yet these policies are not translated into the BRs or building codes by planning authorities. Furthermore, most buildings in the region are small-scale residential structures, constructed using traditional or non-engineered methods by local communities. To improve safety, it is essential to develop simplified design guidelines tailored to these common building types. Such provisions would ensure better protection for individuals who may not have the financial means to invest in professionally designed buildings or expensive modern materials [7].

For these strategies to work policy direction needs to be given so that regulatory authorise revise the current BRs for example the Sustainability Housing Guidelines (SHGs) introduced in Zambia to aid in sustainable building practices are rarely used in regulating housing construction.

3. Materials and Methods

The objective of the study was to investigate the level of adaptation of BRs to climate change in selected developing countries in Africa. The study was an in-depth desktop literature review using comparative analysis with qualitative data and no inferences made. Ten (10) countries in Africa (Zambia, Kenya, South Africa, Egypt, Nigeria, Tanzania, Ethiopia, Ghana, Botswana and Seychelles) were selected based on similar BRs inherited from Britain. Primarily through a word search in google scholar of all the ten countries BRs, codes and journal articles was undertaken as shown in (Figure 1). The keyword combinations were structural integrity, energy efficiency, lighting, ventilation, and sustainable sites (20 records).

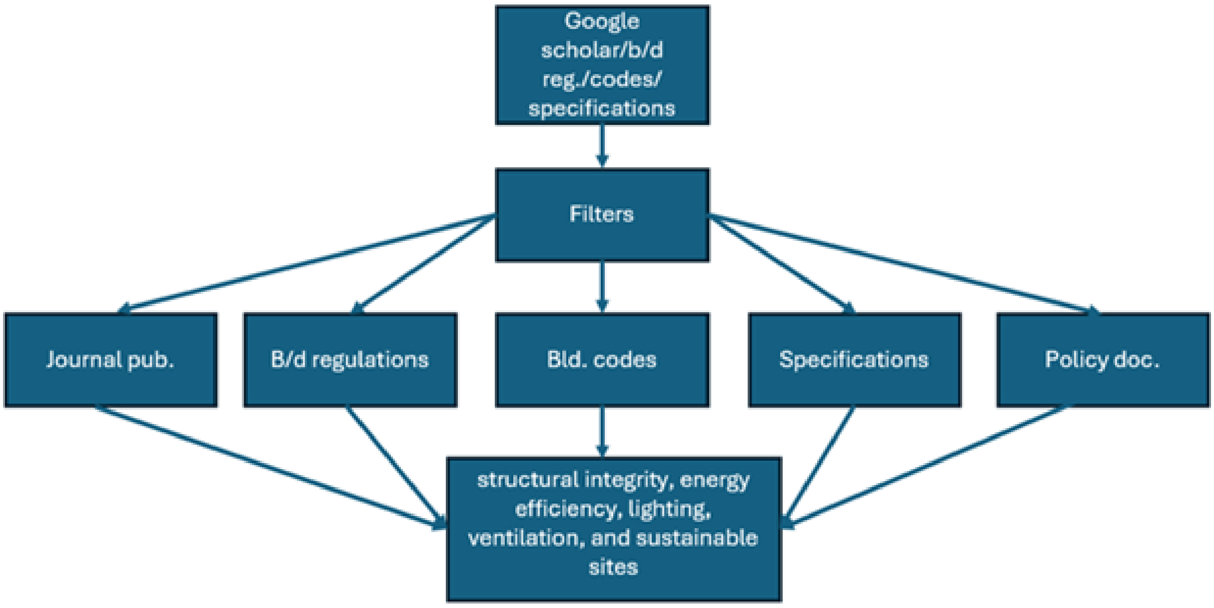


Figure 1. *Literature review flowchart.*

4. Results and Discussion

4.1. Energy Efficiency Codes

The study revealed that BRs implicitly addressed issues of sustainability. The results show that of the countries that have revised their building regulations in the last decade (Kenya, Ghana, South Africa, Nigeria, Tanzania, Ethiopia, and Seychelles) more codes aligned to adaptation to climate change. While existing regulations provide guidance on adequate lighting and ventilation, they fail to address conditions of extreme heat or the efficient use of energy in such scenarios. The assumption in the current BRs is that the codes are sufficient to mitigate and adapt to climate change.

Though countries have common strategies for achieving energy efficiency each country has unique challenges that come because of varies environmental difference for example topography, land formation or even the adopted land use plans. Egypt, Ghana, and Ethiopia incorporate special considerations for seismic forces in their building regulations, ensuring that structural loading accounts for these activities to enhance stability and resilience in earthquake-prone areas. Zambia faces special challenges due to severe weather patterns, including years of drought followed by years of flooding. The country also uses a lot of biofuels and only 11% of the rural area is electrified.

Table 1 shows the comparison based on lighting, ventilation and water utilization. All the countries promote the use of windows for natural ventilation, illumination, roof lights and artificial lighting but do not include compact designs for passive solar gain or using trees to act as sunshades and wind breakers. In some countries, BRs do not incorporate essential energy-efficient measures such as proper insulation for walls and roofs, light-colored surfaces to reflect solar radiation, or provisions for green roofs and walls. However, South Africa (SANS10400-XA), Kenya (NBC Part X 160.(5)), Ghana and Seychelles emphasize compact building designs, strategic orientation to optimize sunlight exposure, reflective materials, and landscaping to enhance energy efficiency. Egypt's regulatory framework (GBL 119 of 2008) includes a natural lighting code and landscape guidelines that enhance interior daylighting. In Nigeria, provisions focus on thermal and acoustic insulation within floors, ceilings, and roofs to improve indoor comfort. Ghana's regulations encourage an East-West building orientation to optimize natural lighting, solar gain, and ventilation. Ethiopia (CES 164 (3.3.2.1)) mandates that buildings exposed to intense sun radiation, particularly those facing west and southwest, incorporate effective radiation protection measures to mitigate overheating.

In many countries, these provisions are incorporated into separate legislative frameworks. For example, in Zambia, the National Climate Change Plan (NCCP) and Sustainability Housing Guidelines (SHGs) outline specific strategies aimed at reducing carbon emissions in buildings. In Kenya the BRs include energy efficiency in the appliance and lighting standards among households but in the Egyptian BRs they are not explicit about energy efficient lighting except in the Electricity Law (Law No. 87 of 2015) and NEEAP [34]. Using solar energy is not in the Zambian BRs but can be found in the NCCP and Zambian Energy Efficiency Strategy and Action Plan (ZEESAP). In the Nigerian BRs there are no specific strategies on energy efficiency except in the National Building Energy conservation Code (BEEC) and the Building Energy Efficiency, which establishes minimum criteria for lowering energy use. Botswana has measures to promote energy efficiency in buildings, particularly through the Botswana Green Building Council (BotGBC) and national legislation. The National Energy Policy (April 2021) and the Integrated Resource Plan for Electricity (October 2020) focus on energy-efficient cooling and sustainable building practices [26]. Tanzania has several laws and initiatives that support building energy efficiency. Initiatives and policies to enhance energy use are outlined in the Tanzania Energy Efficiency Action Plan (EEAP). Furthermore, the National Energy Efficiency Strategy (2024–2034) places a strong emphasis on using efficient building practices to lower greenhouse gas emissions and power usage [27].

Table 1. *Energy efficiency and water utilization codes.*

Country	Description of codes	Missing climate adaptable regulations
Zambia	-Blds not to affect the light and ventilation of other blds (BRs Sec 75 clause 19) -Every room has at least one window opening (BRs Sec 75 clause 45(1))	-Insulation in walls and roofs, light coloured walls and roofs -Use of landscape and shading devices -Building compact design -LED lighting not specified -No solar photovoltaic panels -No rainwater harvesting codes -No high-efficiency flush toilets and Wash Hand Basin (WHB) taps with a reduced flow rate
South Africa	- shading with veranda, balcony, fixed canopy, eaves, or shading hood (SANS10400-5.2.1 (a)) -Thermal insulation for walls, roof and ceilings, that contribute to the thermal barrier, (SANS10400-5.6.1(a)) -Use the orientation of the bld. to control heat gain (SANS10400) -Materials to control heat gain or cold in buildings (SANS10400-XA) -Domestic solar water heaters and solar collectors to comply with 6.1.2 -Water-efficient plumbing fixtures to reduce consumption. (SANS) 10252-1: 2012	-Insulation in walls and roofs, light coloured walls and roofs -Use of landscape and shading devices -Building compact design -LED lighting not specified
Kenya	-Rooms with least one opening on an external wall, or roof (NBC part X 133 (1)) Natural lighting, cooling and ventilation to be provided (NBC part X 160. (1)) -Bld. to have systems to collect and drain rainwater from roofs and a provision for rainwater harvesting. (NBC 2021 282(1)) -Renewable energy sources like solar panels, (L. N. No. 103 of 2012) -Prevent heat gain by, landscaping and sun shading devices (NBC part X 160. (5))	Insulation in walls and roofs, light coloured walls and roofs -no use of LED lighting -Building compact design
Egypt	-Natural lighting code, land planning elements on interior daylighting (GBL 119 of 2008) -75% buildings to be covered with solar photovoltaic cells (UBL No, 119 2008) -Limits on building heights to prevent inadequate light and ventilation (GBL 119 of 2008) -Building to have one or more openings to a street/ court for light and vent.	-Shading devices and landscaping to reduce direct sunlight and heat gain - Light coloured walls and roofs -Building compact design -LED lighting not specified

Country	Description of codes	Missing climate adaptable regulations
Nigeria	-Buildings on same plot: should constitute adequate sources of light and ventilation (CAP. 6.1.2) -The minimum openable area to the outdoors shall be 4% of the floor area being ventilated 6 (CAP. 6.1.3) -Every room shall have natural and artificial light and ventilation CAP 6.1.2.1) -shall provide cross ventilation on at least two approximately opposite sides. (CAP 6.2.7.2) -Thermal and acoustic insulation located on or within floor-ceiling and roof -Use of solar collectors which function as building components (CAP. 5.20) -A room with a water closet be separated from food storage by a tight-fitting door	-Shading devices and landscaping to reduce direct sunlight and heat gain - Light coloured walls and roofs -Building compact design -LED lighting not specified -No efficient use of water, water recycling or rainwater harvesting
Botswana	-Building to be provided with sufficient water (Cap 65: 02 19(1)) -Every dwelling shall be constructed to have two external walls with windows openable area of not less than $0.1m^2$ (CAP. 65: 2, 66(1)) -provision of water closet, bathtub and urinal in specific area (CAP. 65: 2, 67(1))	-No provision of high-efficiency flush toilets that use and Wash Hand Basin (WHB) taps with a reduced flow rate, not exceeding 6 liters per minute - No use of shading devices or landscape for controlling heat -No recycling, rainwater harvesting, and the effective use of taps and flushing systems
Tanzania	-Every room intended to be used as a living or sleeping room shall be ventilated (CAP. 355) 76(1)) -A plot to make adequate provision for harvesting rainwater or carrying off rainwater, surface-water, waste-water or sewage from the plot (CAP. 355) 77(1))	-Insulation in walls and roofs, light coloured walls and roofs -Use of landscape and shading devices -Building compact design -LED lighting not specified -No solar photovoltaic panels -No high-efficiency flush toilets and Wash Hand Basin (WHB) taps with a reduced flow rate
Ghana	-Buildings shall normally be oriented on the East-West axis to take care of natural lighting, solar penetration and ventilation. -Every habitable room to have a window and ventilation openings for cross air movement NBR (LI 1630) (3a) -Energy efficiency in mechanical ventilation, hot water systems and lighting (part 14 (clause 37.5) -Roof to have an outer covering or finish with a high thermal resistance. NBR (LI 1630) (92)(1)) -Vegetative roof garden complies with the requirement of the fire code -Photovoltaic panels will be installed according to the requirement of ASTM D3161	-Compact designs or shading devices and use of landscape to reduce heat in the bld. -No provision of high-efficiency flush toilets that use and Wash Hand Basin (WHB) taps with a reduced flow rate, not exceeding 6 liters per minute -No use of shading devices or landscape for controlling heat
Ethiopia	-Windows and openings to all building facing intense sun radiation (facing west and south-west) to be provided with effective radiation protection (CES 164 (3.3.2.1) - Windows min. area of opening part not less than one twentieth of the floor area (CES 164 (4.11.1.5.1)) -All buildings other than dry regions shall be provided with roof water harvesting mechanisms and can retain their surface water on lot. (CES 164 (8.3.7-8))	-The codes factors in the penetration of intense sun radiation but there is no mention of the use of shading devices and the use of landscape to shield the sun. -there is no provision for solar energy use -Provision for ventilation but not mentioned compact designs and use of building orientation to capture prevailing winds -No life cycle of the building and use of its component recover and re-use existing construction materials

Country	Description of codes	Missing climate adaptable regulations
Seychelles	-Every building used shall be equipped with sufficient supply of potable water (Act 55 of 2021) 38 (48)) -All new buildings must include water harvesting and storage facilities (Act 55 of 2021) 50(1)) -Every building to be adequately ventilated (Act 55 of 2021) 55(1)) -Buildings oriented for optimal ventilation, minimal exposure to solar radiation and natural cooling -Steeply pitched roofs to ensure more sunlight for photovoltaic panels or solar water heaters (Act 55 of 2021)(60)) -New buildings to have solar power systems for hot water supply (Act of 2021)(6))	No provision for efficient flush toilets not exceeding 3 L for a 1/ 2 flush) and 6L for a full flush and WHB reduced flow rate of taps not exceed 6 L/minute - There is no mention of compact designs or shading devices and use of landscape to reduce heat in the bld

Ghana's building regulations include energy efficiency requirements, primarily outlined in the Ghana Building Code (2018). This code sets standards for sustainable construction, including mechanical systems, lighting efficiency, heating, ventilation, and air conditioning (HVAC) systems [28]. Ethiopia's standards for energy consumption and conservation are among the measures outlined in Energy Regulation No. 447/2019 to increase energy efficiency in buildings and industry [29]. The energy efficiency strategies of Seychelles have been clearly stipulated in their building regulations and are the most detailed among the countries understudy.

Countries like Kenya, South Africa, Egypt, Nigeria, Ghana and Seychelles talk about having solar collectors on roofs but do not give specifications on installation. All the countries, except Zambia, state rainwater collection in their regulations, yet they lack specific installation guidelines. In contrast, other legislation offers more comprehensive details than the actual BRs. The challenge is whether the solution shown in national strategies is adequate to enforce these laws in building designs and construction. All the countries under study recognize the importance of energy efficiency in their building sector, however guidelines are missing in most of them, thus it is hard to enforce these strategies and an opportunity is lost to incorporate mitigation and adaptation strategies in buildings [30].

The reduction of carbon emissions is vital in making buildings adaptable to climate change, as evidenced by industrialised countries with energy codes such as the Nearly-Zero Energy Buildings (NZEB) standards by 2021, which aim to reduce the carbon emissions from buildings owing to energy use [6]. Other authors suggest improvement like weatherproofing, enhance insulation in walls, roofs, and floors, use of double or triple-glazed windows to minimize heat loss, efficient HVAC Systems and LED Lighting.

In South Africa, even if rainwater harvesting is not explained in detail in the BR, institutional setups and local laws allow for its adoption and control at the municipal level. Rainwater harvesting is not stated in the Zambian BRs, but it is mentioned in NCCP. In Egypt rainwater harvesting is not included in the BRs but they are developing a countrywide rainwater harvesting plan [30].

4.2. Structural Integrity Codes

The outcomes for structural integrity are summed up in Table 2. Building stability, fire resistance, and soundness are key in all the BRs but there is no mention of water proofing in flooded buildings, and use of sustainable building materials. Egypt, Nigeria and Ghana mention solutions for wind loads and earthquake effects or seismic forces but none of the countries provide building codes for managing floods or excessive heat within structures. However, they do establish regulations for efficient water drainage and removal from sites.

Some countries like Nigeria mention that all weather-exposed surfaces shall have a weather resistive barrier to protect the interior wall covering and this assumes that the water entering the site is due to normal rainfall. None of the regulations explicitly address reducing the life cycle cost (LCC) of materials, nor do they focus on material renewal and reuse. However, South Africa, Kenya, and Egypt emphasize minimizing construction waste. Additionally, South Africa, Ghana, Seychelles, and Kenya specify thermal capacity requirements for building walls to enhance energy efficiency.

Structural integrity was dealt with without consideration to mitigate floods, strong winds, and high temperature in buildings. The challenge that most of these countries have are outdated regulations that do not include green building best practices and this is supported by other authors that metropolitan planners and decision-makers need to reinforce resilience and adaptation strategies to tackle the increasing impacts of natural hazards [31-33].

Cities must apply strategies in accordance with their individual challenges. For example, Egypt BRs should include materials that will withstand forces from sandstorms, floods and earthquakes. The BRs have placed an emphasis on structural sound buildings in ordinally environmental conditions, but none mention issues of tackling flood flashback, storms and landslides. No BRs is addressing ecologically conscious and resource-efficient methods to be implemented at every stage of a structure's lifecycle as support by [32]. If cities are to address the issues posed by climate change, the current BRs must be revised. Strategies must be implemented in accordance with the difficulties that each country is encountering.

The current codes do not deal with the challenge of global warming because there are assumptions that the heat generated in buildings can simply be extracted by sufficient window openings, cross ventilation and use of artificial ventilation. The codes need to be revised so that buildings become more energy efficient thus reducing global warming and its effect. The challenge also is whether the solution seen in other countries BRs is appropriate for all the countries, or that each country need specific energy efficient codes that can be applied and adequately enforced.

Though the countries understudy have revised their regulations these revisions are scattered across varies legislation and not in one BR document. In the World Bank, report of 2023, on the state of developing countries BRs, it was noted that sustainability is becoming more and more important, yet many construction codes still do not provide clear criteria for renewable energy use, water conservation, or energy efficiency. This point has been supported by [22] who mentioned that the disparity in the codes impedes the creation of resilient and sustainable structures. If the current codes are not modified and updated, they will remain obsolete and not be useful in achieving energy efficient buildings. As observed by [24], International frameworks like the Paris agreement adopted by several countries that encourage zero-carbon emission, are not there in the current BRs in most African countries.

Table 2. *Structural integrity.*

No.	Item description	Missing climate adaptable regulations
Zambia	-Bld. protected with damp-proof course, or stoneware to prevent the access of damp or water to the wall ((BRs Sec 75 clause 31) -Roofs built with solid materials to prevent rainwater from entering the inner surface -Bld. to transmit all the dead superimposed loading BRs Sec 75 clause 32 (12))	-With extreme rain and flash floods, no provision is made for such -No provision made for heavy winds and storms -No provision made for local sourced building materials
South Africa	-Bld. to prevent moisture from penetrating the structure (SANS 10400 Part J) -design of overhangs, gutters, and drainage systems, to direct water from the bld. (SANS 10400 Part L) -durable materials like concrete, brick, and stone for buildings exposed to rain (SANS 10400 Part K)	-Consideration for flash floods and stagnant water -Need for local materials that will protect buildings from infiltration of water -Provision of materials that can withstand flush floods and stagnant water
Kenya	-Construct a wall capable of resisting the penetration of water into any part of the building (NBC part X 116(1)) -A design of a building, structure and any component thereon shall take into account a wind load. (NBC part X 81(1)) -Bld. erected to avoid waterlogging and poor drainage (NBC part X 38(1)) -Bld. erected to prevent wind load (NBC part X 81(1)) -Walls erected to carry load and resist the penetration of water (NBC part X 65(a)) -The design for an earthquake load shall be in accordance with KS EN 1998 (NBC part X 82(1))	-Building to consider storms and hails -Need for local materials that will protect buildings from infiltration of water
Egypt	-Checking of wind load and pressure on structures (ECP-201) -use of recycled, recyclable or reused materials in building with a minimum percentage of building materials used	No provision for flash floods and gushing winds
Nigeria	-All weather-exposed surfaces shall have a weather resistive barrier to protect the interior wall covering. U. B. C Standard No. 17-1 for Kraft waterproof building paper (CAP. 5.13.4	-It caters for protection of buildings from water but does not explain what to use to prevent flooding, and strong winds in bld.

No.	Item description	Missing climate adaptable regulations
Botswana	-Balconies, landings, exterior stairways and similar surfaces exposed to the weather and sealed underneath shall be waterproofed. -The site shall be drained and protect the bld. against damage from moisture and prevent moisture from the ground to the upper surface of the floor -No wall should transmit moisture from the ground to any material in the construction (CAP. 65: 2, 25(2)) -Concrete walls should have resistance to crushing of not less than 10N/mm for solid and 5N/mm for hollow (CAP. 65: 2, (c))	-While it addresses safeguarding buildings from water damage, it lacks guidance on measures to prevent flooding and withstand strong winds. -The materials used to withstand normal load are given but in extreme weather no specification are given
Tanzania	concrete blocks are used in the construction of the walls of a building with the standard cement, sand and stones (CAP. 355) 58	Recommends construction for normal climate but does not specify in situations of flooding, excessive winds and high temperatures
Ghana	-The subsoil of the site shall be effectively drained to protect the building against damage from moisture if waterlogged, damp or susceptible to seasonal flooding NBR (LI 1630) PART III (2) - Any external wall shall be so constructed as not to allow moisture from rainfall to pass to any part of the building NBR (LI 1630) PART III (1) - Buildings and other structures shall be designed and constructed to safely resist earthquake effects or seismic forces	There is consideration to control flooding and earthquake effect on bld. but special materials have been considered to prevent flood water into the bld
Ethiopia	Masonry units and mortar to be appropriate for durability and comply with the requirements stated in (3.15, ES 3088)	The walls factor in ordinary forces and specifications for earthquake effects or seismic forces are given, however factors of flooding, storms and extreme heat are not stated
Seychelles	-In building the roof, external shell and parts, shall be sufficiently weather-proof (Act 55 of 2021)(10)) -Building walls to be constructed as to prevent the passage of moisture from the ground to the walls (Act 55 of 2021) 8(1)) -Wind loads shall be calculated in Code of Practice: (Act 55 of 2021) (c))	Materials recommended for normal climate but does not specify in situations of flooding and high temperatures

4.3. Sustainable Sites

In Table 3, the selected BRs approached sustainable site development in different ways. However, a common limitation among them was the minimal emphasis on landscaping strategies to mitigate the heat island effect except in Seychelles. Additionally, there was little effort to reduce the environmental impact of construction activities to safeguard biodiversity. The Kenyan, SA and the Egyptian BRs talk about keeping the trees on site. Additionally, there was minimal focus on efficiently managing waste through reuse and recycling except in the SA and Seychelles BRs. In Seychelles, BRs highlight the use of local resources to support the economy, along with the incorporation of eco-labeled materials to promote sustainability. In Zambia the preservation of trees is found in other legislation like the Town and country planning Act. Most of the BRs mention the control of dust on site and waste management. The Egyptian laws consider the part of sustainable transportation because it addresses storage and bicycle parking lots. All the countries consider site drainage, but the Kenyan one includes rainwater harvesting on sites. Botswana has programs to promote sustainable construction, such as turning plastic trash into building materials like bricks and tiles [35]. Additionally, the Botswana Green Building Council promotes a circular built environment by encouraging the use of locally sourced and recycled materials but these are not found in the current BR. The Tanzanian BRs focus on minimizing ecological impact through foundation design, controlling construction noise and dust, managing waste sustainably, and reducing the carbon footprint.

Table 3. *Sustainable sites.*

No.	Item description	Missing climate adaptable regulations
Zambia	-Not to erect dwelling on made ground, with street sweepings, or refuse (BRs 75 (17) (1)) - Buildings erected not to cover more than two-thirds of the plot (BRs 75 (7) 10 (1))	-Landscape to control surface water on site and the heat island effect -reuse and recycling of materials on site - protection of biodiversity -efficient transport system
South Africa	-Caution for unstable land, ground movements caused by land-slip, or slope subsoils that may cause foundation movements (SANS 10400 (G)) -waterlogged sites to be provided to a stormwater (SANS 10400 (P)) -Bld. sites to be dust free limited (SANS 10400 (F))	-Landscape to control surface water on site and the heat island effect -reuse and recycling of materials on site - protection of biodiversity -efficient transport system
Kenya	-A landscaped design shall show all installations, show existing trees, natural areas, location trees) (NBC 2021 330 (1)) -If the site is waterlogged or saturated, a drainage shall be provided to direct the water away from the plot to a storm water drain (NBC 2021 330 (50)(2)) -Excessive rubble, rubbish, other debris to be removed within the period specified in the notice. (NBC 2021 330 (53))	- Landscape to control heat island effect -reuse and recycling of materials on site - protection of biodiversity -efficient transport system
Egypt	-building to have 929 sqm to have a change room, a shower and bicycle parking site (UBL No, 119 2008) -trees to be native or adaptive to the region (UBL No, 119 2008)	-Landscape to control surface water on site and the heat island effect -reuse and recycling of materials on site -efficient transport system
Nigeria	-Material shall not cause an excessive amount of dust shall be wet down to prevent the creation of a nuisance (clause 12.1.7.1) -Rare trees and other plant species shall be preserved and developed into botanical garden	- Landscape to control heat island effect -reuse and recycling of materials on site -efficient transport system
Botswana	Site to be well drained and surface water channeled from blds	There is no provision for biodiversity, landscaping and us of sustainable materials
Tanzania	-Drainage systems should be designed with positive outfalls to prevent ponding and include provisions of suitable discharge outfalls or soaka-ways (CAP. 4.2.3.2.4) -The design of foundations should account for their impact on sensitive species, the management of noise and dust during construction, and the generation, reuse, and disposal of waste materials and the carbon footprint of the construction (CAP. 4.2.3.5)	-Landscape to control the heat island effect -reuse and recycling of materials on site -efficient transport system
Ghana	-The subsoil of the site shall be effectively drained if waterlogged, damp or susceptible to seasonal flooding (PART III—20(2)) -To ensure, that sites are prepared with adequate provision for the preservation of ecological values and for the planting of trees; (PART III—26(1a)) - Law prohibit the cutting down, topping, lopping or willful destruction of trees (PART III—27(2))	-Landscape to control the heat island effect -reuse and recycling of materials on site -efficient transport system
Ethiopia	All blds. shall have planting amounting to at least 15% of their lot area and new buildings and additions over $50m^2$ shall be landscaped (CES 164 (3.3.4.2))	-Landscape to control surface water on site and the heat island effect -reuse and recycling of materials on site -efficient transport system
Seychelles	-Consider the life cycle of the building and its components —recover and re-use existing construction materials (Act 55 of 2021) (65) 1) -Easy dismantlement of the building components for re-use and recycling -Use local resources to support local economies and eco-label materials	

No.	Item description	Missing climate adaptable regulations
	(Act 55 of 2021) (65) 2(a)) -Use vegetation to mitigate the effects of temperature, humidity, and contamination (Act 55 of 2021) (65) 2(f)) -Reduce the heat island effect by using roofing and ground coverings with low heat absorption levels (Act 55 of 2021) (65) 2(g)) -Building not built in a park, nature reserve or conservation area ((Act 55 of 2021) (69) (a)) -Landscape design for ecosystems and biodiversity, for local biotic zones; (Act 55 of 2021) (70) 2(a)	

Other legislation with climate change strategies is more uptodate than most BRs. For example, South African considers sustainable buildings in SANS 10400 XA within the South African National Standard. The Environmental Management Act, 2011 (EMA), the National Adaptation Plan (NAP), and the National Council for Construction (NCC) Act of 2020 all indicate responses to climate change in Zambia, but very little is seen in BRs.

Designing and adopting building standards has often been a top -down directive that does not sufficiently consult with stakeholders including both private buildings, professionals and local communities. As a result, some nations have borrowed unaffordable standards from foreign countries. Thus, BRs in low-income countries have often set bars too high creating dependency on imported building materials which are stifling local innovations. So, for developing countries the regulations may be different but following the industry's best practices.

The need to amend the BRs has been ongoing for many nations, due to the changes in the materials and design specifications but in essence these amendment have been slow for most countries. A building's durability and strength can be successfully increased using safety measures, reliable materials, low-emission designs, and cutting-edge technologies [33].

5. Conclusion

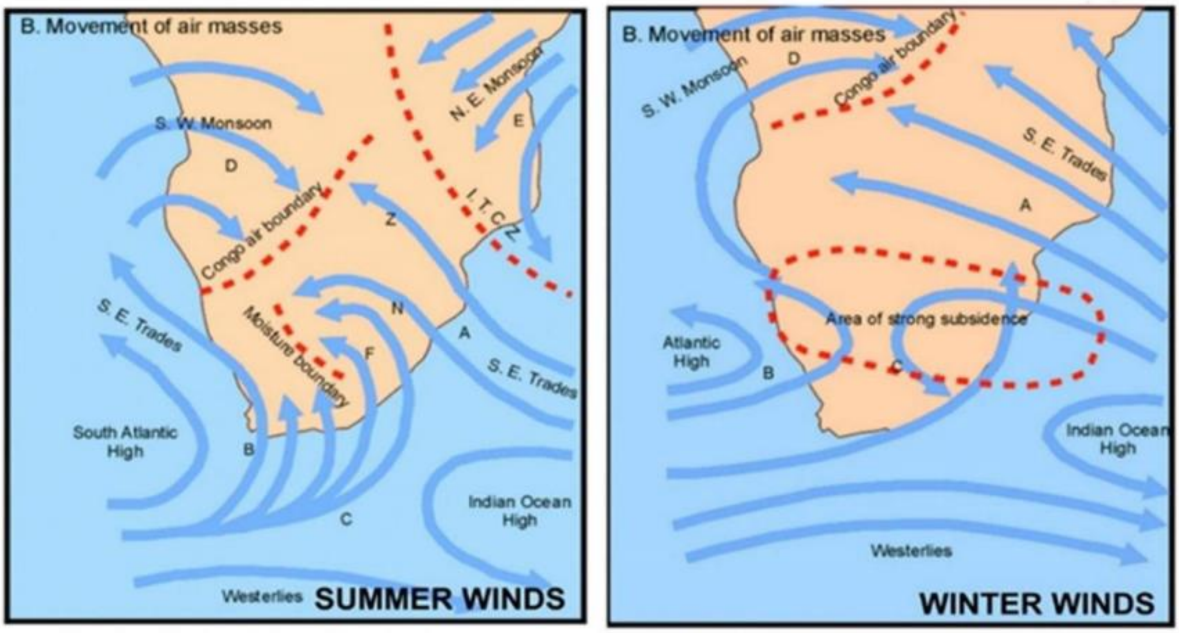
To effectively address climate change challenges in the built environment, African nations must revise their outdated BRs, many of which stem from colonial-era policies. These antiquated regulations often fail to promote climate resilience, making it difficult for developers to construct sustainable and adaptable buildings. The findings of this study highlight the urgent need to update BRs, as those with more recent revisions have demonstrated greater applicability in mitigating and adapting to climate change. A significant challenge identified in this study is the prevailing assumption that structural integrity alone is sufficient to achieve building resilience. While ensuring buildings are structurally sound is fundamental, true resilience requires a more comprehensive approach, one that integrates energy efficiency, resource conservation, climate resilience, and environmentally responsible design principles. The study highlights significant gaps in African BRs regarding climate change adaptation and energy efficiency. Adaptation to climate change strategies are scattered across multiple policy documents, making them inaccessible to key stakeholders. Most codes focus on structural integrity, cross ventilation, and protection from water seepage. Energy efficiency provisions remain limited, typically mentioning solar collectors while neglecting compact designs, LED lighting, insulation, and reflective surfaces. Less common strategies, such as roof and wall gardens and shading devices, could greatly enhance efficiency but are rarely included. Sustainable water utilization is largely confined to references to rainwater harvesting, yet without clear installation guidelines. Furthermore, critical water-saving features like low-flow toilets and wash hand basin taps are mostly absent. The study findings show that sustainable site strategies received minimal attention, with only a few codes addressing them. To meet international best practices, African countries must establish a more integrated and accessible regulatory framework, ensuring a climate-adaptive built environment that promotes long-term resilience and sustainability.

6. Recommendations

Across Africa, innovative strategies are being adopted to mitigate the impact of climate change on buildings. These strategies can be integrated into the revision of BRs and are recommended as follows:

1. Application of SANS 10400X (South Africa)

Buildings should be orientated to make use of the prevailing winds (see figure 2) to cool the building through natural ventilation.



(Source: https://www.uj.ac.za/wp-content/uploads/2023/11/sans-10400-xa)

Figure 2. *Prevailing winds of South Africa.*

1) Shading

Shading against summer solar radiation can be provided by

a) shading devices,
b) glass tinting and coating,
c) fenestration types and design, or
d) size of area of glazing per elevation.

2) alternatively have an external shading device, such as a shutter, blind, building screen with vertical or horizontal blades, battens or slats, which can restrict at least 80% by area of astronomical summer solar radiation, and if adjustable, is readily operated either manually, mechanically, or electronically by the building occupants.
3) suspended floor that is part of a building's envelope shall have insulation that will retain its thermal properties under moist conditions and an insulation R-value of 1,5 m^2 K/W or R-value of 1,0 m^2 K/W.
4) The minimum total R-value requirements for an external wall for buildings other than category 1 buildings with a surface density equal or greater than 270 kg/m^2
5) Minimum total R-value (24-30m^2 K/W) of roof and ceiling materials (Roof covering includes outside air film, non-reflective unventilated air space and plasterboard only)

2. Strategies taken from THE NATIONAL BUILDING CODE, 2022 of Kenya

A landscape layout design may be combined with the landscape planting design that shows:

1) the type or botanical name, of a plant and the planting quantity and the proposed location for a tree, shrub, perennial or ground cover
2) a typical and applicable planting detail, and a unique planting installation, road island and median cross section planting installation and
3) a planting design that shall identify a proposed surface treatment

3. Strategies taken from BUILDING) REGULATIONS, 2024 of Seychelles

1) Water harvesting- All new buildings, extensions or renovations must include water harvesting and storage facilities commensurate to the water usage capacity of the building. Every rainwater storage tank for water harvesting shall be made of durable materials and watertight.
2) Every new building must be oriented in such a way that optimal ventilation, minimal exposure to solar radiation during the peak hours of the day and natural cooling is ensured. Furthermore, steeply pitched roofs must be oriented in a northerly direction to ensure more sunlight for photovoltaic panels.
3) In all new buildings or any rehabilitation, rebuilding or extension shall have solar power systems for hot water supply.
4) Material efficiency- Consider the life cycle of the building and its components —
5) Recover and re-use existing construction materials and components;
6) Design for easy dismantlement of the building component to allow for re-use and recycling;
7) Adequate management of waste produced by the building process in order to reinsert recyclable materials into the production process and thus reduce material sent

to landfills;

8) efficient design — use modular design strategies to reduce waste;
9) use lightweight building materials to reduce the weight of the building;
10) favour recycled and/or recyclable materials, reducing the demand for virgin materials.
11) Consider the building's flexibility for use in the future, so that it can be redeveloped and used for different purposes;
12) incorporate strategies to properly protect exposed parts of the building, using materials that don't have to be replaced frequently;
13) low-maintenance finishings that are easy to clean;
14) Use environmentally friendly materials —Use local resources and materials whenever possible,
15) supporting local economies and reducing the ecological footprint left by transportation;
16) Use materials with eco-labels or carbon footprint declarations;
17) Use plant-based products from renewable sources with short re-growth cycles (25 years);
18) Use vegetation to mitigate the effects of temperature, humidity, and contamination;
19) Reduce the heat island effect by using roofing and ground coverings with low heat absorption levels;
20) Respect natural and/or cultural heritage zones and avoid sensitive areas —
21) Possess documents that prove the project is not being built in a park, nature reserve or conservation area;
22) Integrate the project into its surroundings through design —Ensure harmony between the architectural elements and surroundings, give priority to interesting visual scenes/staging;

4. Revision of Building Regulations: To meet the objectives of climate resilience, governments must update and change the current BRs. Rather than merely accepting European standards, these revisions should be customised to meet local environmental and societal concerns.
5. Undertaking a bigger systematic review of current building regulations thus including more countries will aid to understand the problem better;
6. Consolidation of Climate Policies: To guarantee that industry stakeholders have access to pertinent regulations, climate change strategies should be combined into a single, easily available regulatory framework;
7. Building Capacity: The planning authority should set aside resources for training all the technical staff in the local government and councils on sustainable building methods and technology so that they participate in the updating and enforcement of BRs and;
8. Make communities aware of the importance of creating sustainable buildings so they may function as the impetus for implementing BRs that take adaptation and resilience into account when designing and building structures.

7. Implications for Practice and Advancement of Research

This study highlighted the significant gap in developing countries achieving climate resilience buildings. It revealed that BRs have very few codes addressing climate change. Through this research, a new interest has emerged in exploring innovative approaches to enhance the adaptability of BRs to climate change. As one of the first publications to examine BRs across multiple countries, it provides a broader perspective on adaptation efforts across the African region. Additionally, this study creates an opportunity for further research on revising BRs to better suit the unique environmental and socio-economic conditions of each region.

Abbreviations

BRS	Building Regulations
BMS	Building Material Specifications
Blds	Buildings
EMA	Environmental Management Act
GHG	Green House Gases
GBRSA	Green Building Council of South Africa
ICC	International Code Council
LCC	Life Cycle Cost
SDGs	Sustainability Development Goals
NAP	National Adaptation Plan
NBCs	National Building Codes
NCC	National Council for Construction
SANS	South African National Standard
SHGs	Sustainability Housing Guidelines
NCCP	National Climate Change Plan
NEBs	Nearly-zero Energy Buildings
SA	South Africa
WHB	Wash Hand Basin
ZEESAP	Zambian Energy Efficiency Strategy and Action Plan

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Mutinta Sichali a member of the Zambia Institute of Architects (ZIA) is an award winner of Green Jobs competition of ILO. She has B. Arch. in Architecture, a master's degree in human Settlement and a PhD in Construction Management. She has 29 years' experience as a consultant and is lecturing at the University of Zambia, School of Public Health. She has authored peer reviewed journal papers to include *An Integrated Green Building Assessment Tool for Low-Cost Housing Development in Zambia* (2021). *A Cross-Sectional Study of Utilization of Green Building Rating in the Zambia* (2020). She has presented papers at the *ZIA international conferences* and *the International Conference on Infrastructure Development and Investment Strategies for Africa*, on the Green Building Movement in Zambia.

Chibesa Mulenga is a seasoned professional in Building and Quantity Surveying with 32 years of experience spanning government and private sector projects in Zambia and Malawi. A lecturer at the University of Zambia for 17 years, his research focuses on Construction Management, Water and Sanitation (WATSAN), and Environmental Management. He has produced working papers and delivered impactful conference presentations, that include *"Construction Project Performance in Zambia" (2021), "Greening Lusaka, Climate Resilience for a Healthier City"*, and "*Climate Change, Cholera Outbreaks, and WATSAN Solutions in Zambia"* (WEDC-2024). Holding a BSc in Building, an MSc in Water and Environmental Management, and a PhD in Construction Project Performance, Dr. Mulenga is also a member of (Zambia Institute of Quantity Surveyors (ZIQS), Engineering Institute of Zambia (EIZ), Fellow Surveyors Institute of Zambia (FSIZ), Member of Royal Institute of Chartered Surveyors (MRICS), and Member Chartered Institute of Buildings (MCIOB), reflecting his commitment to advancing the field.

Research Field

Mutinta Sichali: Sustainable building designs, climate change resilience materials, development of local building materials, modelling technics in indoor climate in hot arid regions, and creation of green cities in landscaping and development of sustainable housing.

Chibesa Mulenga: Construction Project Performance, Water and Sanitation improvement in Africa, and Sustainable project management in school buildings, cost control in low-cost buildings, control of water borne diseases in low-cost housing, facility management in public schools, and sustainable Project Management in low income countries.