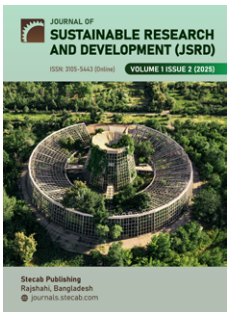

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Resilient Urban Future: Climate-Responsive Design and Sustainable Construction in Afghanistan's Varied Climate Zones

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About Article

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ABSTRACT

This study examines the broad impact of climate change on global urban growth and construction dynamics, with a particular focus on the diverse climatic zones within Afghanistan. It addresses a critical research gap: the significant disparity between the adoption of modern construction methods and the limited use of climate-responsive techniques in the region. The research employed a mixed-methods methodology, analyzing survey data from 300 respondents across three cities representing Afghanistan's major climate zones: Kabul (cold continental), Jalalabad (arid), and Asadabad (temperate). The findings indicate a considerable transformation in construction methods towards contemporary global standards; however, they also reveal a critical misalignment with local climates. Key quantitative results show low awareness of climate-responsive principles and notable urban deficiencies, including widespread energy inefficiency (reported by up to 45.1% of respondents in city planning) and a severe lack of green zones (deficient in 75.2% of Kabul). Furthermore, the study identifies a predominant reliance on low-cost materials (over 64% across all zones) and poor building alignment. The study concludes that urban growth, marked by an absence of formal planning, intensifies these challenges. We advocate for tailored climate strategies and enhanced planning, specifically recommending zone-specific building codes, mandatory climate-responsive design integration, and targeted urban greening programs to effectively address these complex challenges.

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1. INTRODUCTION

The term "*sustainability*" refers to a system's inherent capacity to endure, continue operating, and sustain itself over a lengthy period. It's common to use the terms sustainability and sustainable development interchangeably (Behsoodi *et al.*, 2023). There are 17 Sustainable Development Goals (SDGs) that aim to accomplish objectives such as "eliminating all forms of poverty globally, guaranteeing that everyone has access to modern, cheap, dependable, and sustainable energy, and "reinvigorating the global partnership for sustainable development." The 13th Sustainable Development Goal (SDG) is Climate Action, which has five objectives for acting quickly to mitigate the effects of climate change, and governmental, non-governmental, and international organizations are working together to achieve the targets in every country. SDG11 "Sustainable Cities & Communities" emphasizes building safe, resilient, inclusive, and sustainable cities and communities around the globe. It aims to address urbanization challenges, improve living conditions, and ensure access to basic services for all (UN SDGs, 2023). So, from the mentioned 17 goals, the 13th one, dedicated to Climate Action, has its five urgent targets aimed at combating climate change and its far-reaching impacts. "Climate change is a ubiquitous factor that affects many different areas, including the development and expansion of cities. It is a global catastrophe rather than just a problem (Smith & Friedman, 2000). According to João *et al.* (2020), understanding key terms is essential to developing resilient urban designs in response to climate concerns.

Our planet is changing due to a combination of factors, including increased waste generation, greater consumption, population expansion, and rising CO2 emissions. Population expansion drives up consumption, which in turn drives up waste production and carbon dioxide emissions. This poses a serious threat to plants and biodiversity (Adhya *et al.*, 2010). To mitigate these concerns, a thorough and sustainable urban design that carefully integrates urbanism and urbanization might be extremely important.

1.1. Urbanism, urbanization, and climate challenges

Urbanization and urbanism are vital forces shaping the modern biosphere, emphasizing functional and sustainable urban environments (King, 2015; Pozoukidou & Chatziyiannaki, 2021). Rapid urbanization, expected to reach two-thirds of the global population by 2030, offers development opportunities but strains energy infrastructure (UNIDO, 2018).

1.2. Urban design

The multifaceted area of urban design shapes cities for visual appeal, functionality, and inhabitant well-being (Gehl, 2010). Urbanism, landscape architecture, planning, and architecture are all integrated, playing a key role in contemporary city development (Duany & Talen, 2002).

1.3. Climate-responsive design

In order to create sustainable urban planning, climate-responsive design combines climatology, biology, and ecology, emphasizing environmental improvement and reduced energy consumption (Tompson, 2012). Early assessment of local climatic conditions and the use of natural energy sources are necessary to overcome obstacles (Bodach, 2016; Tavel, 2011).

1.4. Sustainable buildings and construction

Sustainable building entails using ethical building techniques, reducing the negative effects on the environment, and promoting social, cultural, and economic advancement (Baloi, 2003). Sustainable buildings aim for zero or positive impacts, reducing resource consumption, energy use, and greenhouse gas emissions (Thomas & Jeffery, 2007; Camaren Peter, 2012). The building sector, accounting for 40% of energy consumption globally, holds significant potential for emission reductions and resource conservation (UNEP, 2010).

Sustainability, addressing ecological, economic, and social dimensions, is explored in the context of urbanization in Afghanistan over a range of climatic zones, seeking solutions for environmental pollution and a greener future.

However, there is a critical lack of empirical research assessing the on-the-ground implementation of sustainable and climate-responsive design within Afghanistan's varied climatic zones. Therefore, this study aims to identify the specific gaps between contemporary construction practices and climate-responsive principles across the cold, temperate, and arid regions of Afghanistan to provide targeted recommendations for resilient urban development.

2. LITERATURE REVIEW

Covering an area of 652,860 square kilometers and housing over 42 million people, Afghanistan is currently undergoing significant demographic shifts. With a natural rate of population increase of about 2.7% annually (Hanif *et al.*, 2021; Worldometer, 2023), the population is notably young, with over 60% under the age of 20, posing substantial implications for its development.

2.1. Urbanization challenges in afghanistan

The way communities are physically laid out and transported is known as urban form, which requires an integrated approach to transformative planning (North Somerset Council, 2007). Afghanistan experiences both opportunities and challenges in its urbanization, with a 4% annual urbanization rate driven by factors like migration and urban boundary extensions (Loft, 2021). Currently, 25.9% of the population resides in urban areas, projected to reach 50% by 2060 (Worldometer, 2023). Informal urbanization contributes to poverty (Schütte, 2009; UN-Habitat, 2014).

2.2. Afghanistan in the view of climate vulnerabilities

Afghanistan's diverse climate presents challenges for urban planners, emphasizing the need for climate-responsive design with an understanding of local conditions and traditional techniques (BRILL, 2023; Mustonen & Ayanlade, 2022). Rising temperatures, notably in central and southwestern regions, pose a significant challenge. The country is set to experience a 1.5°C temperature increase by 2050 and an additional 2.5°C by 2100 (VNR Afghanistan, 2021; UNEP, 2016). Climate change is a result of greenhouse gas emissions, mainly CO_2 emissions, with Afghanistan's 2019 emissions at 28.79 million tons (Zaki & Lederer, 2023).

2.3. Priority and strategic vision of afghanistan national environmental protection agency (NEPA)

NEPA, Afghanistan's primary environmental policy authority, was founded in 2005, regulating and enforcing environmental laws (Qazi, 2009). Priorities include resilience, climate-conscious planning, sustainable progress, and increased awareness (NEPA, 2020). Strategies involve promoting eco-friendly building practices, sustainable construction, and energy-efficient lighting, alongside the construction of structures that are fire and soundproof (NEPA, 2020).

While existing literature outlines the climatic vulnerabilities and urbanization challenges in Afghanistan, a synthesized analysis that empirically evaluates the adoption of climate-responsive design and construction practices across its distinct climatic zones is absent. This study fills this gap by systematically investigating the disparity between modern construction methods and sustainable, climate-adaptive techniques in the cities of Kabul, Jalalabad, and Asadabad.

3. METHODOLOGY

A mixed-methods approach was employed, combining quantitative and qualitative data. Quantitative data were gathered through a survey distributed via Google Forms to a purposive sample of 300 residents, construction professionals, and local authorities across the three target cities (Kabul, Jalalabad, and Asadabad. The survey had a response rate of 84%, yielding 252 completed responses. Qualitative data were collected through direct observational site visits to assess urban form and building characteristics, as well as through semi-structured interviews with 15 selected experts from relevant municipal and environmental agencies. MS Excel was used to analyze the quantitative data, while thematic analysis was applied to the qualitative insights. The study findings are communicated more effectively, thanks to the tabular representations of the data.

4. RESULTS AND DISCUSSION

4.1. Results

This study combines a variety of viewpoints and includes active participation from experts, city workers, authorities, and residents. The accompanying tables attentively illustrate the fascinating results of this collaborative work, offering a visually accessible platform for improved understanding.

Table 1. Exploration of building construction methods.

Climate Zones (City)	Traditional Approaches (%)			Contemporary Methods (%)	
	Adobe	Natural Brick	Brickwork	Concrete with reinforcement	Brickwork
Temperate (Asadabad)	60.40	30.20	9.40	67.90	32.10
Arid (Jalalabad)	66.20	33.80	-	68.80	31.20
Cold Continental (Kabul)	38.40	54.30	7.30	69.50	30.50

Table 2. Environmental consciousness and design adaptation to climate change

Climate Zones (City)	Attending Climate Change Training Sessions (%)		Comprehension of Climate-Responsive Design Principles (%)	
	Yes	No	Yes	No
Temperate (Asadabad)	12.10	87.90	49.70	50.30
Arid (Jalalabad)	35.20	64.80	64.50	35.50
Cold Continental (Kabul)	17.30	82.30	51.00	49.00

Table 3. Key features of climate-adaptive urban design

Climate Zones (City)	Deficient in Energy Efficiency (%)			Green Zones (%)			Cityscape Greenery (%)			Cultivation (%)			Changes in Temperature (%)		
	City Planning	Structures	Infrastruc-tures	Adequate	Limit	Unsatisfied	Perennial	Autumnal	Mixed	Close	Remote	Absent	Rise	Decline	Consistent
Temperate (Asadabad)	43.0	33.0	24.0	31.7	55.2	13.1	27.1	54.2	18.7	86.1	13.9	-	97.2	-	2.8

Arid (Jalalabad)	45.1	30.0	24.9	14.0	73.6	12.4	36.9	56.9	6.2	76.4	23.6	-	95.0	-	5.0
Cold Continental (Kabul)	39.2	34.9	25.9	8.1	75.2	16.1	40.1	33.1	26.8	24.7	38.2	37.1	99.0	-	1.0

Table 4. Examination of eco-friendly approaches in building development

Climate Zones (City)	Energy Source Analysis (%)				Building Layout (%)		Building Material Decision Making (%)				Thermal Insulation Section (%)		
	Hydroelectricity	Solar Energy	Hydropower & Solar	Petroleum & solar	East to West Transition	North-to-South Transition	Heat-resistant	Cool-resistant	Anti-heat & Cool	Cost-effective Materials	Openings	Entire Structure	Nil
Temperate (Asadabad)	11.3	56.6	24.5	7.6	60.4	39.6	34	-	1.9	64.1	24.5	-	75.5
Arid (Jalalabad)	55.8	28.6	11.7	3.9	44.2	55.8	49.4	-	-	50.6	6.5	-	93.5
Cold Continental (Kabul)	47	4.0	21.9	27.1	53.6	46.4	-	24.5	7.9	67.6	30.5	2.6	66.9

Table 5. Environmental effects of urban expansion

Climate Zones (City)	Heating System for Buildings (%)				Transportation System (%)			Waste Management System (%)				Industrial Facility (%)		
	wood	Gas	Coal and Wood	Hydropower	Public transit	Local transit	Others	Durable	Fine	Weak	Unsatisfied	Exist	Not exist	Not Considerable
Temperate (Asadabad)	62.3	37.7	-	-	-	94.3	5.7	-	22.7	37.7	39.6	-	62.3	37.7
Arid (Jalalabad)	51.9	27.3	3.9	16.9	-	100	-	-	19.5	67.5	13	54.5	20.8	24.7
Cold Continental (Kabul)	23.8	4	72.2	-	-	98.7	1.3	-	11.9	53	35.1	68.9	10.6	20.5

4.2. Discussion

The shift from traditional to modern construction methods, as shown in Table 1, indicates a move towards globalized building standards. However, the low comprehension of climate-responsive principles revealed in Table 2 explains why this modernization is not synonymous with sustainability. This creates a critical vulnerability: buildings are becoming more modern yet less suited to their local environments, locking in long-term energy inefficiency and occupant discomfort.

The data in Table 3 exposes a systemic failure in urban planning. The high percentages of energy inefficiency and deficient green zones across all cities are not merely statistical shortcomings; they are direct drivers of the urban heat island effect, which is corroborated by the near-unanimous reporting of rising temperatures. Kabul's situation is particularly alarming, as the proximity of agricultural land to the urban core suggests unchecked sprawl is consuming the very landscapes that could provide ecological buffer zones.

Table 4 reveals a paradox: while clean energy like solar power is being adopted, the fundamental logic of building design remains dominated by cost and divorced from climate. The overwhelming selection of cost-effective materials over heat- or cool-resistant ones indicates a severe market and knowledge failure. In Jalalabad's arid climate, for instance, the 93.5% lack of thermal insulation is not just an oversight; it guarantees high indoor temperatures and a massive future demand for energy-intensive cooling, undermining the benefits of solar power.

Finally, the environmental impacts detailed in Table 5 paint a picture of a high-carbon urban system. The reliance on wood and coal for heating, especially in Kabul, coupled with weak waste management, creates a feedback loop that exacerbates air pollution and public health crises. The continued operation of industrial facilities within city limits, as reported in Kabul and Jalalabad, points to a lack of zoning enforcement, directly sacrificing urban livability for informal economic activity.

5. CONCLUSION

The following conclusions were reached following a thorough analysis of innovations, climate responsiveness, sustainability, and developments in cities throughout Afghanistan's many climatic zones, including desert, mild, and cold (continental) regions:

- The climate policies and plans of the Afghan National Environmental Protection Agency were deemed to be overly generic and devoid of specific factors that were specially developed for every different climatic zone.
- The absence of formal planning in Afghanistan's urban growth has led to its fast expansion and restricted access to decent housing, which has exacerbated the effects of climate change and increased poverty.
- There are several obstacles to improvement because of the absence of climate awareness, which exposes a large discrepancy between the adoption of climate-responsive techniques and evolving building characteristics.
- There are deficiencies in several important areas of climate-responsive urban design, including inadequate green space, energy efficiency, and poorly maintained urban greenery, all of which raise temperatures.
- Despite the use of clean energy, buildings frequently have low-quality materials, inadequate insulation, and poor alignment, making them unsustainable and climate-unsuitable.
- Uncontrolled carbon emissions from industrial facilities, waste management, transportation, and building heating have a major impact on residential surroundings, precipitation patterns, and general quality of life.

RECOMMENDATION

The study's conclusions lead to the following recommendations and ideas being put forth:

- Afghanistan's environmental guardian, the National Environmental Protection Agency (NEPA), should improve its protection plans and match national goals with the country's varied climate.
- Raise public awareness, NEPA should start effective initiatives to raise understanding of climate change, including pertinent subjects in school curriculum, and make use of social media.
- To encourage greener and more intelligent urban design, the Ministry of Urban Development and Housing should include sustainable practices in city legislation. These practices include building orientation, energy saving, adherence to green space requirements, and climate-specific urban forestry.
- Reduce carbon emissions in cities, municipalities should aggressively support sustainable energy systems in buildings, push for carbon-free mobility with bike lanes, enhance garbage disposal, and think about moving manufacturing outside of cities.

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