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Climate Responsive Green Building Strategies in Circular Cities: A Comparative Study for Two Regions

Mirjana Miletić [1,*], Dragan Komatina [2] and Marija Mosurović Ružičić [3]

[1] Department of Architecture, Faculty of Technical Sciences, University of Priština in Kosovska Mitrovica, Knjaza Miloša 7, 38220 Kosovska Mitrovica, Serbia
[2] Department of Architecture, Faculty of Architecture, University of Montenegro, Karađorđeva 5, 81000 Podgorica, Montenegro; komatinadragan@gmail.com
[3] Institute of Economic Sciences, Zmaj Jovina 12, 11000 Belgrade, Serbia; marija.mosurovic@ien.bg.ac.rs
* Correspondence: mirjana.miletic@pr.ac.rs; Tel.: +381-638584697

Abstract: This paper provides a comparative analysis of green building strategies in circular cities from an architectural perspective. It focuses on Belgrade, Serbia, which has a temperate continental climate, and Podgorica, Montenegro, with a mild subtropical climate. The data were gathered through an online questionnaire disseminated among 140 architects in both cities. A five-point Likert scale was applied, and the data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 23). Descriptive statistics, factor analysis, reliability testing, and group comparison methods were employed to ensure a valid, reliable, and transparent framework for processing and interpreting the research of data. By analyzing locally available materials, technologies, and climate factors, the research found that the adoption of circular economy principles does not significantly differ between the cities. This suggests that economic and policy-related factors may have a greater influence than initially expected. Additionally, there was no significant difference in the integration of greening strategies integration (p = 0.08), challenging the assumption that climate-responsive design would lead to distinct variations in urban form. However, locally available materials and technologies had a stronger impact on green building practices in Serbia (p = 0.01). The study highlights that sustainable architecture is shaped by a combination of local resources, regulatory frameworks, and socio-economic conditions rather than climate factors alone. These insights contribute to the theoretical advancement of climate-smart green building strategies in circular cities. They provide valuable guidance for practitioners and policymakers. Future research should further explore the interplay of socio-economic and regulatory influences to refine strategies for climate-responsive and circular architecture.

Keywords: green building strategies; circular cities; sustainable architecture; Belgrade; Podgorica; locally available materials

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1. Introduction

A circular city operates on the principles of a circular economy, striving to minimize waste and maximize resource efficiency through recycling, repurposing, and sustainable systems [1]. Climate-responsive design, on the other hand, adapts buildings and urban spaces to their specific climate by employing passive strategies such as natural ventilation, thermal mass, and renewable energy to reduce environmental impact [2]. These concepts intersect in their common pursuit of sustainability—by incorporating climate-responsive design, circular cities become more energy-efficient, resilient, and environmentally balanced [3].

1.1. Green Building Practices and Circular Economy

As urbanization accelerates and environmental concerns grow, the integration of sustainable development principles within urban planning and architecture has become critical [4,5]. Circular cities, which aim to eliminate waste and make the most of resources through reuse, recycling, and regeneration, present a forward-thinking model for sustainable urban development [6,7]. In the context of these cities, green building strategies play a key role in achieving environmental goals, particularly by reducing energy consumption, minimizing waste, and enhancing resource efficiency [8–11].

When it comes to green building practices in the context of the circular economy, the literature highlights the increasing implementation of sustainable building solutions. These include the integration of bio-based materials [12,13], digital and Artificial Intelligence (AI) solutions [14,15] and policy-driven sustainability strategies [16] to improve climate resilience and energy efficiency.

However, the literature suggests that sustainable building practices reduce energy consumption, minimize environmental impacts, and improve residents' health and well-being through the use of innovative technologies and materials [17]. Green buildings have become a focal point in recent years because of their ability to reduce environmental impact, improve energy efficiency, and enhance the well-being of their occupants [18]. The increasing body of research highlights different strategies in green building design, such as passive methods to reduce energy use, the incorporation of renewable energy sources, and the use of bio-based and recycled materials to foster sustainability [19].

1.2. Green Building Approaches and Innovative Solutions

Green building approaches play a crucial role in achieving sustainability, especially within the construction industry. Green building is designed to reduce environmental consequences and mitigate effects on occupants. To attain the objectives of green buildings, changes on the management level are needed [20]. Organizational culture and leadership are critical to fostering green innovation. This underscores the need to link organizational principles with sustainability goals to foster a culture that supports innovative practices [21], which foster business performance [22].

Innovative green building solutions integrate advanced technologies to enhance energy efficiency, reduce environmental impact, and improve occupant well-being. Smart building systems, using IoT-enabled devices and sensors, optimize energy consumption by adjusting lighting, heating, and ventilation based on real-time conditions. Building-integrated photovoltaics (BIPV) allow buildings to generate their own energy through solar panels integrated into roofs and facades, contributing to energy independence. Green walls and living facades improve insulation, reduce the urban heat island effect, and enhance air quality by incorporating plants into building exteriors. High-performance glazing systems, such as low-emissivity (Low-E) glass, reduce heat transfer and optimize daylight, boosting energy efficiency and comfort. Rainwater harvesting systems collect and store water for non-potable uses, decreasing reliance on municipal supply. Additionally, zero-carbon buildings, which produce as much energy as they consume, are becoming a key feature of sustainable architecture.

Green building strategies integrate comfort conditions while integrating principles of the circular economy, aiming to reduce waste, promote material reuse, and optimize the life cycle of buildings [23]. Key approaches include passive design techniques such as natural ventilation, shading, and thermal mass to reduce reliance on mechanical heating and cooling systems [24]. Energy efficiency is enhanced through high-performance insulation, smart building systems, and the integration of renewable energy sources like solar panels and geothermal heating [25]. Water conservation measures, such as rainwater harvesting and gray water recycling, contribute to urban sustainability by reducing strain on municipal water supplies [26]. Additionally, green roofs and urban vegetation improve air quality, mitigate the urban heat island effect, and enhance biodiversity [27]. In the broader urban context, green building strategies support resilient cities by promoting adaptable architecture, reducing carbon footprints, and creating healthier environments for residents [28]. They are essential in addressing climate change and fostering long-term urban sustainability. However, the effectiveness of green building strategies is highly influenced by local climatic conditions [29]. In different climate zones, the architectural approaches to sustainability vary significantly due to the need to adapt to specific environmental factors [28].

1.3. Research Questions

This study focuses on two cities, one located in a mild subtropical climate and the other in a temperate continental climate, to examine how these distinct environments shape green building practices within the framework of circular cities

While numerous studies explore green building practices, there is a paucity of comparative analyses focusing on how architects in diverse climatic regions implement climate-responsive strategies. The existing literature often centers on single-case studies or generalized approaches, lacking insights into region-specific challenges and adaptations.

Research questions tailored for the two cities in different climates are:

RQ1: How do architects in Belgrade (Serbia) and Podgorica (Montenegro) with different climates integrate climate-responsive strategies into green building designs, and what challenges do they face in implementing these strategies?
RQ2: What are the key differences in the application of circular economy principles in green building projects between cities with different climates considering their distinct climate zones?
RQ3: How do locally available materials and technologies in cities with different climates influence the adoption of climate-responsive green building practices in line with circular city objectives?

The objective of this research is to compare climate-responsive architectural strategies in these two climates, focusing on energy efficiency, material usage, and resource management. By analyzing the ways in which each city, Belgrade (Serbia) and Podgorica (Montenegro), addresses its unique environmental challenges through green building practices, the study seeks to provide insights into how circular cities can optimize sustainability across different climate zones. The findings will underscore the importance of climate-adaptive design within circular economy frameworks, highlighting how architecture can contribute to the resilience and sustainability of future urban environments. The successful implementation of climate-responsive design strategies can guide architects and urban planners in the optimal use of architectural and urban design techniques to enhance indoor and outdoor thermal comfort while mitigating risks to human health and energy security. These insights will furnish evidence-based and practical design solutions for architects and urban planners throughout the initial planning phase to alleviate the potential effects of increasingly frequent high heat occurrences, energy, water use and resource efficiency.

This research utilizes a mixed-methods approach, combining a structured questionnaire survey to explore how architects, with experience in designing residential and public buildings for a minimum of 5 years, in Belgrade (Serbia) and Podgorica (Montenegro), integrate climate-responsive strategies and circular economy principles in green building designs. The questionnaire focuses on the adoption of climate-responsive strategies, challenges in implementation, and the use of locally available materials and technologies. Data were collected using Likert scale questions, enabling a quantitative analysis of responses, while qualitative interviews will provide deeper insights into specific challenges and strategies employed by architects.

The outcomes include identifying key differences in the application of circular economy principles across cities with different climates, understanding how locally available materials influence sustainable practices, and revealing any variations in urban form and architectural appearance based on climate-responsive strategies. The findings will contribute to the development of more effective sustainable building practices and circular city objectives, offering practical recommendations for architects, urban planners, and policymakers.

2. Literature Review

The key climate challenges consequently incorporated into the questionnaire, which was distributed to architects, serve as the foundation for this research.

2.1. Climate Adaptive Architecture and Urbanism

Climate change and urbanization have intensified environmental challenges, requiring climate-responsive and sustainable design strategies [30,31]. Rising global temperatures increase cooling demands, making passive cooling strategies like shading, thermal mass, and natural ventilation essential [32]. High humidity affects both comfort and material durability, necessitating vapor-permeable materials and adaptive ventilation [33]. Increasingly unpredictable precipitation demands stormwater management solutions such as green roofs and permeable surfaces to prevent urban flooding [34]. Urban heat islands intensify urban temperatures due to heat-retaining surfaces, but reflective materials and green infrastructure can mitigate their effects [35]. Energy efficiency remains a key challenge, requiring passive design, smart materials, and renewable energy integration to reduce environmental impact [36]. Addressing these challenges through climate-responsive architecture is essential for resilient and sustainable urban development.

The integration of green building strategies into circular cities is based on the principles of the circular economy, including resource efficiency, waste minimization, and regenerative design [37]. Sustainable architecture in this context involves the use of recycled and bio-based materials, energy-efficient and modular construction, as well as passive design strategies such as natural ventilation and daylight optimization [38–40].

Climate-adaptive architecture is essential for sustainable urban development, as research emphasizes the need for climate-responsive design strategies [41] to enhance building performance and minimize environmental impact [42,43]. In subtropical regions, passive cooling techniques—such as shading, cross-ventilation, and the strategic use of materials—help reduce cooling demands [44]. Studies on vernacular architecture offer valuable knowledge on traditional methods that naturally align with modern sustainable design principles [45].

The application of circular economy principles to architecture and urban planning has gained momentum in recent years [46,47]. Studies emphasize the role of modular design, material recovery, and adaptive reuse in reducing construction waste and extending building [37]. The concept of circular construction, which integrates closed-loop material flows and design-for-disassembly strategies, has been proposed as a key solution for sustainable urbanization [48].

Several comparative studies have analyzed the impact of climatic conditions on sustainable building practices [49]. Findings from comparative studies suggest that tailored strategies based on regional climatic contexts significantly improve energy efficiency and occupant comfort, that subtropical cities prioritize ventilation and solar shading to mitigate overheating, and that temperate continental cities focus on insulation and heat retention to address seasonal temperature variation [50–57]. The integration of circular design strategies into these climate-adaptive approaches provides a comprehensive framework for achieving self-sustaining urban ecosystems. Research supports the argument that a combination of passive design, renewable energy integration, and material circularity fosters long-term resilience and resource efficiency in urban environments [58,59].

The reviewed literature underscores the significance of climate-adaptive and circular design strategies in promoting sustainable urban development [58,60–63]. The intersection of circular economy principles with climate-responsive architecture presents a promising pathway for enhancing energy efficiency, reducing waste, and improving building resilience across diverse climatic conditions [64].

The urban form and integration of greenery in cities that implement circular economy principles are strongly influenced by their respective climate zones. In warmer climates, cities tend to feature compact urban forms with shaded public spaces, green roofs, and vertical gardens to mitigate heat, while in colder climates, urban layouts prioritize solar exposure, wind protection, and the use of seasonal green infrastructure [65,66]. The availability of local materials and sustainable construction technologies further shapes the spatial organization, façade treatments, and landscape strategies, resulting in distinct visual identities and functional characteristics that reflect both ecological and cultural adaptations [67,68].

In addition to field research on the same topic and a comparison of practice from the view of professionals in two regions, the paper provides an overview of indicators based on literature research that are recognized by architects, relating to the circular city, climate, and urban environment.

2.2. Circular City Indicators

Circular city indicators are metrics used to assess the sustainability and resource efficiency of urban environments [69]. These indicators typically include factors such as waste reduction, material recycling, energy efficiency, renewable energy usage, and water conservation. Additionally, they measure the adoption of circular economy principles in areas like transportation, construction, and food systems to promote a closed-loop urban economy [70]. From an architect's perspective, circular city indicators focus on evaluating how urban designs incorporate sustainability and resource efficiency. Key indicators include the use of renewable energy sources, the integration of sustainable building materials, and the implementation of waste reduction strategies such as material recycling and reusing. Additionally, these indicators assess the incorporation of circular economy principles into urban planning, including the design of energy-efficient buildings, green infrastructure, and systems that promote water and resource conservation [71,72].

Urban greenery plays a vital role in addressing the interconnected challenges of circular urban planning, climate resilience, and sustainable development. By integrating greenery into the urban environment, cities can enhance resource efficiency, improve environmental quality, and support social well-being [73,74].

The following table provides an overview of the implementation of key indicators in Belgrade and Podgorica that illustrate the connections between greenery, the circular city concept, climate adaptation, and the urban environment (Table 1). These environmental indicators serve as a framework for understanding how green infrastructure and practices contribute to achieving sustainability goals in diverse urban and climatic contexts as it was presented in the empirical research [75].

Table 1. Implementation of Circular City Environmental Indicators (CCEIs) for Belgrade and Podgorica cities.

CCEIs			**Belgrade**		**Podgorica**
Environmental Indicators	Green Infrastructure	Horizontal and vertical greenery Urban green areas	Yes	A more intensive application is necessary for both cities for all indicators	Yes
	Microclimate regulation	Temperature regulation Humidity control Different urban climate zones	Partially		Partially
	Material Circularity in Green structures	Reuse Recycling Adaptive reuse Landscaping	No		No
	Energy Efficiency through Bioclimatic design	Application of trees and green facades to reduce cooling or heating	Yes		Yes
	Urban Density and Green Spaces	Urban greenery and its acces	No		No
	Climate responsive Landscaping	Selection of plants based on climate conditions	Yes		Yes
	Water management	Water recycling Use of green spaces	No		No

Source: Author's research based on [75].

Green infrastructure indicators in cities refer to the integration of natural elements like parks, trees, and green roofs to manage environmental challenges. Microclimate regulation, through these green areas, helps moderate temperatures, reducing heat island effects, especially in areas without trees or vegetation [76]. Material circularity in green structures focuses on using sustainable, recyclable materials in construction. Urban areas without green spaces may lack this benefit, leading to increased waste and environmental strain [77]. Energy efficiency through bioclimatic design promotes building strategies that adapt to local climates, yet streets without green areas are more likely to have higher energy demands due to poor heat regulation. Urban density and green spaces are closely linked; cities with limited green areas suffer from lower quality of life and reduced environmental resilience, whereas climate-responsive landscaping in these spaces can mitigate heat and improve air quality, which is absent in built-up areas devoid of vegetation [78].

The figure offers a section of the circular city indicators related to recently developed green infrastructure, urban density, and green spaces (Table 1), in both cities, that actually highlights their deficiency in both cities (Figure 1).

Due to the lack of space and construction within the urban core of both cities, after the year 2000, the focus has been placed on residential areas, with less attention given to the urban environment (Figure 1). There is a scarcity of greenery, minimal distance between buildings, and a disregard for the application of bioclimatic parameters [79].

Figure 1. Residential buildings in Belgrade, Serbia (the above images), and Podgorica, Montenegro (the below images), built after 2000. Source: Authors.

3. Methodology

The methodology consisted of multiple elements, including explanations, the development of a questionnaire, data collection, and statistical analysis.

The online survey was specifically designed for practitioners in Serbia and Montenegro and was structured into three logical sections. The study ensured an equal number of participants from both countries, with one hundred forty (140) total responses received, guaranteeing a balanced representation in the dataset. Architectural engineers pursuing doctoral studies in sustainability and resilience of the built environment, as well as professionals with a minimum of five years of work experience, were included. The first section collected general information about the architects, such as their geographical location and years of professional experience. It also explored how architects in Belgrade and Podgorica incorporate climate-responsive strategies into green building designs and the challenges they encounter during implementation, explaining which passive greening strategies they most commonly use in their projects.

The second part examines the key differences in how circular economy principles are applied in green building projects in Belgrade and Podgorica, taking into account the unique characteristics of their respective climate zones, providing an explanation of what the circular city represents for them and how familiar they are with its concepts and indicators.

The third part of the questionnaire provides insights into how locally available materials and technologies in Belgrade and Podgorica impact the adoption of climate-responsive green building practices aligned with circular city objectives.

Architects evaluated five statements related to circular city indicators in architecture, using a five-point Likert scale ranging from 1 (Not at all) to 5 (Extremely). The collected data were analyzed using Statistical Package for the Social Sciences (SPSS) software, with the analysis including descriptive statistics, reliability testing, correlation analysis, and non-parametric tests to assess differences between groups from different countries.

3.1. Research and Questionnaire Design

This research is based on the concepts of sustainable architecture, the circular economy, and climate-responsive strategies in green building design. Sustainable architecture focuses on designing buildings that minimize environmental impact while optimizing resource and energy efficiency [80]. The research questions are built on these theoretical foundations to explore how architects in different climate zones integrate climate-responsive strategies into green building design. Particular focus is on implementation challenges, differences in the application of circular economy principles, and the influence of locally available materials and technologies on adopting sustainable practices in line with the circular city concept [81,82].

The data were collected via a questionnaire in which the respondents assessed various statements on a five-point Likert scale (1—Not at all; 5—Extremely). The statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS) software and involved descriptive statistics, exploratory factor analysis, reliability analysis, parametric and non-parametric tests for comparing differences between groups [83].

A Principal Component Analysis (PCA) was independently conducted on three distinct sets of items to identify key factors within each domain. The first set examined five items measuring the degree of integration of greening strategies. The second set analyzed five items evaluating the degree of application of circular economy principles in projects. The third set assessed five items measuring the impact of the availability of local materials and technologies on adopting green building practices specific to different climate zones.

3.2. Hypothesis Development

This research is based on the concepts of sustainable architecture, the circular economy, and climate-responsive strategies in green building design. Sustainable architecture focuses on designing buildings that minimize environmental impact while optimizing resource and energy efficiency [84]. The research questions are built on these theoretical foundations to explore how architects in different climate zones integrate climate-responsive strategies into green building design. Particular focus is on implementation challenges, differences in the application of circular economy principles, and the influence of locally available materials and technologies on adopting sustainable practices in line with the circular city concept [85–87].

Building upon the insights gained from the literature review and empirical research, this section delves into the core research questions that guide the investigation of climate-responsive strategies and circular economy principles in green building practices in two countries, Serbia and Montenegro.

Defined research questions provide a comprehensive framework for understanding the intersection of climate, design, and sustainability in urban contexts.

The hypotheses are developed based on the idea that climate conditions, local materials, and technology shape circular city strategies [88]. **H1** assumes that differences in material availability and technology influence how circular economy principles are applied in green buildings across climate zones. **H2** suggests that climate-responsive strategies impact urban form and architectural identity, leading to variations in building materials, spatial organization, and esthetics between cities with different climates.

To explore the topics discussed further, the following hypotheses were developed:

H1: *The application of circular economy principles in green building projects differs across climate zones due to variations in locally available materials and technologies, influencing the extent to which climate-responsive and circular city objectives are achieved.*

H2: *The urban form and architectural appearance of cities implementing circular economy principles in different climate zones vary significantly, as climate-responsive strategies shape building materials, design typologies, and spatial organization, leading to distinct esthetic and functional characteristics in the built environment.*

3.3. Sample Description

Architects from Serbia (Belgrade) and Montenegro (Podgorica) who participated in the survey identified key climate challenges specific to their respective cities. Figure 2 illustrates the number of respondents from each country who mentioned each climate challenge.

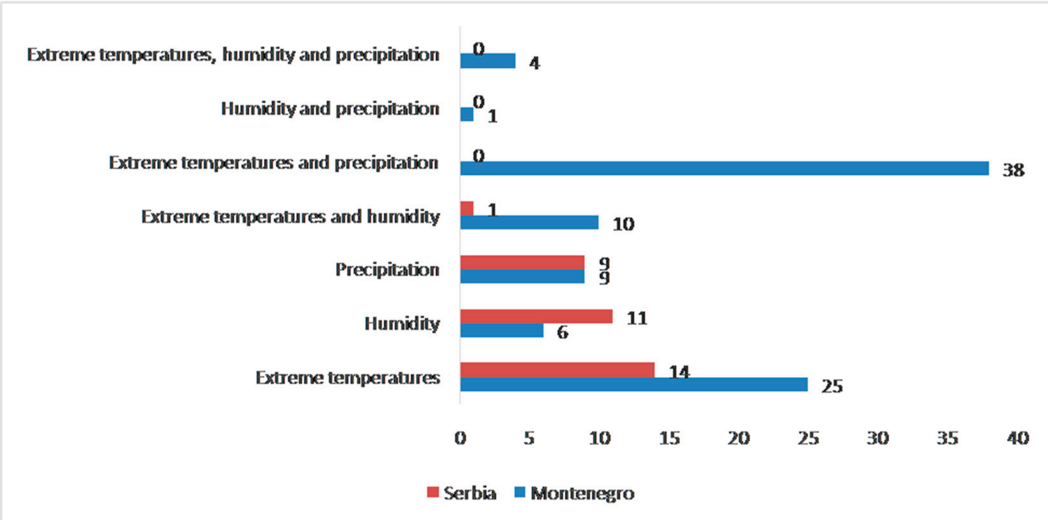

Figure 2. Key climate challenges, results from 140 responses received. Source: Author's research.

Figure 3 illustrates architects' perspectives on what a circular city represents in Montenegro (Podgorica) and Serbia (Belgrade). Among the respondents, 58% from Montenegro and 49% from Serbia indicated that a circular city represents circularity (e.g., circular functioning, reuse, from materials to energy). Additionally, 18% of respondents from Montenegro and 27% from Serbia associated a circular city with sustainability (e.g., sustainable architecture).

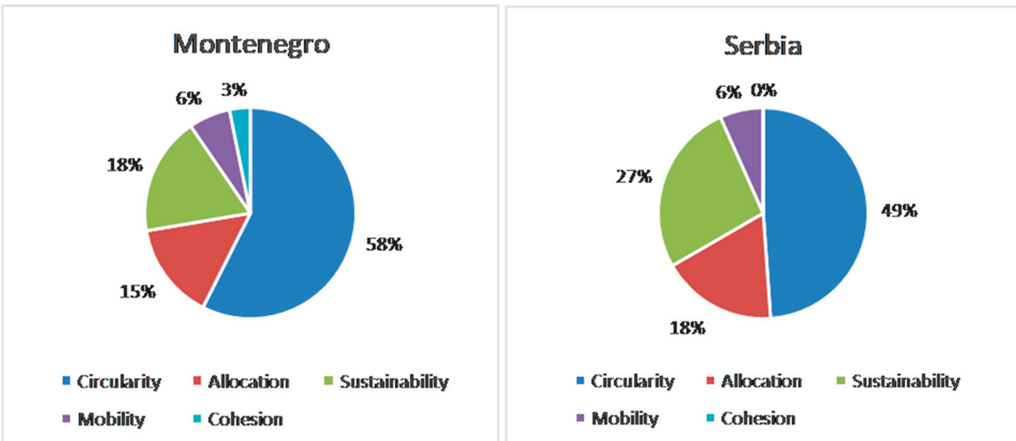

Figure 3. What does a circular city represent for architects? Results from 140 responses received. Source: Author's research.

A smaller proportion—15% from Montenegro and 18% from Serbia—viewed a circular city as representing allocation (effective spatial and functional allocation). Fewer respondents from both countries identified a circular city with mobility (sustainable mobility and traffic) or cohesion (sustainable neighborhoods).

3.4. Data Analysis

The Kaiser–Meyer–Olkin measure confirmed good sampling adequacy for the first set of items (KMO = 0.680), the second set of items (KMO = 0.636), and the third set of items (KMO = 0.793), and Bartlett's test for sphericity ($\chi2(10) = 103.27$, $p < 0.001$; $\chi2(10) = 132.89$, $p < 0.001$; $\chi2(10) = 231.21$, $p < 0.001$) showed that the correlations between the variables were sufficiently high for PCA. Table 2 summarizes exploratory factor analysis results for the degree of integration of greening strategies and presents descriptive statistics for each item.

Table 2. Descriptive statistics for each item and summary of exploratory factor analysis results for the degree of integration of greening strategies.

Item	Factor Loadings	Descriptive Statistics	
		Mean	Std. Deviation
1. How often do you consider local climate conditions in the early stages of design?	0.66	1.93	1.08
2. Are you familiar with the term "passive greening strategies" in building design and construction?	0.68	2.36	1.19
3. Do you use local materials that are adapted to the climate of your region?	0.70	2.05	1.05
4. Do budget constraints affect the implementation of these climate-adapted strategies?	0.70	2.20	1.00
5. Are there specific challenges related to laws and regulations in your city that impact climate-adapted design?	0.55	2.59	1.11
Eigenvalue	2.17		
% of variance	43.39		
Cronbach's Alpha	0.67		

Extraction method: Principal Component Analysis. Source: Author's research.

Eigenvalues were calculated for each component, revealing one component with an eigenvalue exceeding Kaiser's criterion of one (2.17). As a result, a single factor representing the degree of integration of greening strategies was extracted, explaining 43.39% of the variance in the data. The sufficiently high factor loadings indicate strong correlations between the items and the extracted factor, supporting its validity.

Cronbach's Alpha was calculated as 0.67. While values above 0.7 are generally considered acceptable, lower values can be expected in studies measuring a wide range of influences [83]. Additionally, the coefficient is influenced by the number of items within a construct, often increasing as the number of items grows. Given that this construct includes only five items, the obtained value of 0.67 suggests that the measurement instrument demonstrates good reliability.

Table 3 presents descriptive statistics for each item and summarizes exploratory factor analysis results for the degree of application of circular economy principles in projects. Eigenvalues were calculated for each component, revealing one component with an eigenvalue exceeding Kaiser's criterion of one (2.31). As a result, a single factor representing the degree of application of circular economy principles in projects was extracted, explaining 46.16% of the variance in the data. The sufficiently high factor loadings indicate strong correlations between the items and the extracted factor, supporting its validity. Cronbach's Alpha is above the threshold of 0.7, indicating that measuring items have high reliability.

Table 3. Descriptive statistics for each item and summary of exploratory factor analysis results for the degree of application of circular economy principles in projects.

Item	Factor Loadings	Descriptive Statistics	
		Mean	Std. Deviation
1. How familiar are you with the concept of circular cities?	0.56	2.79	1.42
2. Do you think that the climate of your city influences the choice of materials?	0.65	1.99	1.10
3. Are there any local policies or incentives that encourage circular economy practices?	0.70	2.93	1.15
4. Do you face challenges in reducing construction waste during design and construction?	0.75	2.64	1.16
5. Do you ensure the potential for material reuse in your projects in any way?	0.71	2.85	1.17
Eigenvalue	2.31		
% of variance	46.16		
Cronbach's Alpha	0.70		

Extraction method: Principal Component Analysis. Source: Author's research.

Table 4 shows the results of the exploratory factor analysis for the degree of impact of the availability of local materials and technologies on adopting green building practices specific to different climate zones. Descriptive statistics for each item are also presented. One factor was extracted as only one component had an eigenvalue above the Kaiser's criterion of one (2.89). This factor explains 57.70% of the variance in the data. All items have sufficiently high factor loadings, and Cronbach's Alpha is above the threshold of 0.7, indicating a high reliability of the measurement items.

Table 4. Descriptive statistics for each item and summary of exploratory factor analysis results for the degree of impact of the availability of local materials and technologies on adopting green building practices specific to different climate zones.

Item	Factor Loadings	Descriptive Statistics	
		Mean	Std. Deviation
1. How often do you consider passive strategies (e.g., solar shading) when selecting local materials for your projects?	0.66	2.44	1.00
2. How often do you use locally developed technologies in your projects to enhance the building's performance?	0.76	2.59	1.20
3. How often do you collaborate with local manufacturers or suppliers to integrate passive strategies through climate-adapted materials?	0.74	2.71	1.13
4. To what extent does the use of local materials and technologies support your commitment to passive design principles?	0.80	2.58	1.03
5. To what extent does the use of local materials and technologies support your commitment to environmental preservation principles?	0.83	2.57	1.05
Eigenvalue	2.89		
% of variance	57.70		
Cronbach's Alpha	0.81		

Extraction method: Principal Component Analysis. Source: Author's research.

Table 5 contains descriptive statistics for the factor scores. The factor scores are standardized with a mean of zero and a standard deviation of one. However, they show relative differences between respondents in the perceived degree of integration of greening strategies, the perceived degree of application of circular economy principles in projects, and the perceived degree of impact of the availability of local materials and technologies on the adoption of green building practices specific to different climate zones.

Table 5. Descriptive statistics for factor scores with the test of normality.

Factors	Country	Descriptive Statistics			Kolmogorov–Smirnov		Shapiro–Wilk	
		N	Mean	Std. Deviation	Statistic	Sig.	Statistic	Sig.
Degree of integration of greening strategies	Montenegro	93	−0.14	0.86	0.09	0.05	0.94	0.00
	Serbia	44	0.27	1.21	0.13	0.08	0.93	0.01
	Total	137	0.00	1.00	0.10	0.00	0.92	0.00
Degree of application of circular economy principles in projects	Montenegro	94	−0.10	0.91	0.06	0.20	0.99	0.53
	Serbia	45	0.21	1.17	0.08	0.20	0.97	0.44
	Total	139	0.00	1.00	0.07	0.20	0.99	0.18
Degree of impact of the availability of local materials and technologies on adopting green building practices specific to different climate zones	Montenegro	94	−0.17	0.89	0.09	0.09	0.98	0.13
	Serbia	44	0.35	1.13	0.12	0.17	0.93	0.01
	Total	138	0.00	1.00	0.08	0.04	0.97	0.01

The results are significant at the 0.05 level. Source: Author's research.

To address the three research questions, respondents were divided into two groups based on the country (and city) where they work: one hundred and forty architects working in Montenegro (Podgorica) and Serbia (Belgrade). Descriptive statistics for factor scores for each subgroup (Montenegro and Serbia) are presented in Table 5, alongside the results of the Kolmogorov–Smirnov and Shapiro–Wilk tests of normality.

A significant result from these tests ($p < 0.05$) indicates that the data are not normally distributed. The findings suggest that, for both subgroups, the data are normally or approximately normally distributed for the following factors: Degree of application of circular economy principles in projects and Degree of impact of the availability of local materials and technologies on adopting green building practices specific to different climate zones. However, for the factor Degree of integration of greening strategies, the Shapiro–Wilk test indicates that the data are not normally distributed. Similarly, the Kolmogorov–Smirnov test shows that the data for the Montenegro subgroup are not normally distributed, while the data for the Serbia subgroup are normally distributed ($p = 0.05$).

The assumption of normality is required for parametric tests, such as the independent sample *t*-test, while non-parametric tests, such as the Mann–Whitney test, do not rely on this assumption. Based on the results of the normality tests, both the independent samples *t*-test (parametric) and the Mann–Whitney test (non-parametric) were employed to examine differences in the integration of greening strategies between architects from different climate zones (Podgorica and Belgrade).

To investigate whether there are differences in the application of circular economy principles in projects and whether locally available materials and technologies influence the adoption of green building practices specific to different climate zones (Podgorica and Belgrade), the independent sample *t*-test was used. The results of this analysis are presented in Table 6.

Since the *t*-test has two variations depending on whether the variances of the two groups (Podgorica and Belgrade) are assumed to be equal, Levene's test for equality of variances was conducted. The results of Levene's test were significant for the factors Degree of integration of greening strategies and Degree of impact of the availability of local materials and technologies on adopting green building practices specific to different climate zones. This indicates that the *t*-test assuming unequal variances should be used for these two factors. Conversely, for the factor Degree of application of circular economy principles in projects, the result of Levene's test was not significant, suggesting that the *t*-test assuming equal variances is appropriate for this factor.

Table 6. Independent sample *t*-test.

Factors		Levene's Test for Equality of Variances		*t*-Test for Equality of Means	
		F	Sig.	t	Sig. (2-Tailed)
Degree of integration of greening strategies	Equal variances not assumed	6.97	0.01	−2.01	0.05
Degree of application of circular economy principles in projects	Equal variances assumed	3.33	0.07	−1.72	0.09
Degree of impact of the availability of local materials and technologies on adopting green building practices specific to different climate zones	Equal variances not assumed	4.17	0.04	−2.70	0.01

The results are significant at the 0.05 level. Source: Author's research.

The independent sample *t*-test for the factor Degree of integration of greening strategies is marginally significant (p = 0.05). Additionally, the Mann–Whitney test yielded a non-significant result (Z = −1.76, p = 0.08). These findings suggest that there are no statistically significant differences in the integration of greening strategies between architects from different climate zones (Podgorica and Belgrade).

For the factor Degree of application of circular economy principles in projects, the independent sample *t*-test result is not significant (p = 0.09), indicating no statistically significant differences in the application of circular economy principles between Podgorica and Belgrade, despite their differing climatic characteristics.

In contrast, the results reveal significant differences (p = 0.01) in the extent to which locally available materials and technologies influence the adoption of green building practices specific to these climate zones. In Serbia (M = 0.35), locally available materials and technologies have a greater influence on the adoption of green building practices compared to Podgorica (M = −0.17).

4. Results and Discussion

Belgrade, as Serbia's capital, has a diverse economy driven by industry, services, and foreign investment, with significant urban development Podgorica, Montenegro's capital, has a smaller economy with a strong focus on services, tourism, and energy, influenced by the country's transition to a market economy and EU integration efforts [89,90]. These economic differences may impact the adoption of circular and green building strategies, as investment capacity, policy incentives, and market demand vary between the two cities. However, they were not taken into account and represent a topic for further research.

H1: *The application of circular economy principles in green building projects differs across climate zones due to variations in locally available materials and technologies, influencing the extent to which climate-responsive and circular city objectives are achieved.*

The results of the study reveal no statistically significant differences in the application of circular economy principles between architects working in Belgrade and Podgorica, as evidenced by the independent sample *t*-test for the factor "Degree of application of circular economy principles in projects" (p = 0.09). This suggests that, despite the differing climates, architects in both cities approach the application of circular economy principles similarly. However, these findings contrast with the underlying expectation that locally available materials and technologies, which vary by climate zone, would have a distinct influence on how circular economy principles are implemented [88–90].

While the results do not fully support H1, it is important to consider that circular economy principles may be applied in other ways, beyond just the use of local materials and technologies. Additionally, factors such as economic conditions, policy frameworks, and awareness of sustainability issues might play a more significant role than initially anticipated. Further investigation into how these factors influence the implementation of circular economy practices could provide a more nuanced understanding of this relationship.

H2: *The urban form and architectural appearance of cities implementing circular economy principles in different climate zones vary significantly, as climate-responsive strategies shape building materials, design typologies, and spatial organization, leading to distinct esthetic and functional characteristics in the built environment.*

The findings regarding the factor "Degree of integration of greening strategies" indicate marginally significant differences ($p = 0.05$) between the two cities, although the Mann–Whitney test showed no significant results ($p = 0.08$). These results suggest that the integration of greening strategies, which is an important aspect of circular city objectives, may not differ significantly between Podgorica and Belgrade, even though the cities' climates are distinct.

However, the more pronounced differences in the factor "Degree of impact of the availability of local materials and technologies on adopting green building practices" ($p = 0.01$) indicate that the availability of locally sourced materials and technologies does influence the adoption of climate-responsive building practices. In Serbia, materials and technologies are more likely to facilitate the implementation of green building practices compared to Podgorica, which might suggest that the functional and esthetic outcomes of architectural projects in Serbia are shaped more by these local resources. This discrepancy could also be linked to the region's historical and cultural context, which might influence the way architects select materials and design buildings to respond to climate considerations [91].

In relation to H2, the study suggests that the architectural form and design elements, including greening strategies, do show some variation between the cities. This variation is likely shaped by both climate-responsive strategies and the available local resources, but the differences are not as pronounced as expected. Consequently, while some distinctions in the urban form may exist due to climate factors and local materials, the findings do not fully confirm that these cities exhibit significantly different urban and architectural forms purely due to climate-responsive strategies. Despite some sustainability initiatives, Serbia and Montenegro lack comprehensive policies that actively enforce circular economy principles in construction, with regulations primarily focusing on energy efficiency rather than material reuse or lifecycle sustainability [92]. Weak incentives for recycling construction waste and limited implementation of circular design guidelines further hinder the transition toward fully circular building practices in both countries.

Previous studies suggest that climate-responsive design significantly influences urban morphology, particularly in extreme climates. These findings align with newer research indicating that socio-economic and regulatory factors may play a larger role in shaping architectural outcomes [91,92].

In conclusion, while there are indications of differences in the way local materials and technologies influence the adoption of green building practices, the hypothesis regarding the distinct architectural characteristics in cities with differing climates remains inconclusive. Further research might explore other variables, such as policy interventions and socio-cultural factors, to gain a clearer understanding of how these factors interact and affect urban form and architectural design.

5. Conclusions

This study aimed to explore the integration of climate-responsive strategies and circular economy principles in green building projects across two cities with differing climates, Podgorica (Montenegro) and Belgrade (Serbia). Through a series of hypothesis-driven research questions, the study examined the impact of locally available materials, technologies, and climate conditions on the adoption of sustainable architectural practices.

The findings indicate that, despite the differing climates of the two cities, the application of circular economy principles in green building projects does not show significant differences ($p = 0.09$), suggesting that factors beyond local materials and technologies, such as economic conditions and policy frameworks, might influence the adoption of these principles. Thus, the first hypothesis (H1) is not fully supported, and further investigation into these additional factors is recommended.

Regarding the integration of greening strategies, the data showed marginal differences between the two cities, with no significant difference in the degree of greening strategy integration ($p = 0.08$), which questions the expected variance in architectural forms influenced by climate-responsive design. The second hypothesis (H2), proposing significant differences in the urban form and architectural appearance of cities in different climate zones, was also not fully supported. However, there were significant differences in the impact of locally available materials and technologies on green building practices ($p = 0.01$), especially in Serbia, where these materials had a greater influence.

Overall, this study demonstrates that, while some differences exist in how locally available materials shape green building practices, the broader integration of circular economy principles and greening strategies appears less influenced by climate zone differences than initially hypothesized. The findings suggest that a combination of local resources, regulatory frameworks, and other socio-economic factors play a significant role in shaping sustainable architectural practices. This study has significant theoretical value as it improves strategies for climate-smart green building in circular cities. This study provides valuable information for practitioners and policymakers focused on developing environmentally sustainable solutions in the building sector. The successful implementation of green building practices requires a strategic approach that allows for the creation of structured management practices that require the active participation of stakeholders, from government to local communities, organizations and architects themselves.

Future research should expand on these aspects to provide a more comprehensive understanding of the factors influencing circular city objectives and climate-responsive architecture.

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