Advancing Environmental Sustainability through Climate-Resilient and Smart Urban Development in Emerging Economies

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Abstract
Rapid urbanization in emerging economies has intensified environmental pressures, including rising energy demand, air pollution, land-use change,climate vulnerability, and infrastructure stress.At the same time, smart urban develop--ment and climate resilience offer important pathways for improving environmental sustai--nability. This study examines the influence of smart urban development and climate reilience on environmental sustainability in emerging economies using secondary panel data. The study adopts a quantitative research design and applies panel regression techniques to assess the relationship among smart urban develop--ment,climate resilience, urbanization, renew--able energy use, energy intensity, GDP per capita, governance quality, and environmental sustainability. The findings indicate that smart urban development has a positive effect on environmental sustainability, suggesting that digital infrastructure, ICT access, smart monitoring systems, and data-driven urban services can improve environmental performa--nce. Climate resilience also contributes positively to environmental sustainability by strengthening adaptive capacity, reducing vulnerability, and supporting risk-informed urban planning. Renewable energy use impro--ves sustainability outcomes, while energy intensity negatively affects environmental performance. The study concludes that emerg--ing economies can advance environmental sustainability by integrating smart urban technologies with climate-resilient infrastructure, renewable energy systems, inclusive governance, and sustainable urban planning. The findings provide useful policy insights for governments, urban planners, environmental agencies, and development institutions seeking to build greener, smarter, and more resilient cities.

Keywords:
environmental sustainability; smart urban development;climate resilience; emerging economies; urbanization; renewable energy; sustainable cities

1. Introduction

Urbanization in emerging economies is increasing rapidly, creating both opportunities and environmental challenges. Cities support economic growth, innovation, employment, and infrastructure development, but they also contribute to rising energy demand, land-use change, waste generation, air pollution, and greenhouse-gas emissions. These challenges are more serious in emerging economies where urban growth is often associated with infrastructure deficits, informal settlements, weak land-use planning, and limited municipal finance (UN-Habitat, 2024; United Nations, 2025). Climate change has further increased the pressure on urban systems. Many cities in emerging economies are exposed to flooding, heatwaves, drought, water stress, and other climate-related hazards. The vulnerability of these cities is influenced not only by climate conditions but also by poverty, inadequate infrastructure, weak governance, and limited adaptive capacity (IPCC, 2022). Therefore, climate-resilient urban development has become essential for protecting lives, infrastructure, ecosystems, and economic

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activities. At the same time, smart urban development offers new opportunities for improving environmental sustainability.

Digital technologies such as sensors, geographic information systems, smart meters, data platforms, and real-time monitoring tools can support better urban planning, resource efficiency, energy management, waste collection, transport systems, and climate-risk monitoring. However, smart city initiatives can only support sustainability when they are inclusive, well governed, and aligned with environmental and social goals (OECD, 2023; Tan & Taeihagh, 2020). Despite growing interest in smart cities and climate resilience, many studies examine these areas separately. Limited attention has been given to how smart urban development and climate resilience jointly contribute to environmental sustainability in emerging economies. This study addresses this gap by examining the influence of smart urban development and climate resilience on environmental sustainability using secondary panel data from emerging economies.

The study contributes to the literature by integrating smart urban development, climate resilience, and environmental sustainability into one empirical framework. It also provides policy insights for governments, urban planners, and development institutions seeking to build greener, smarter, and more resilient cities in emerging economies.

2. Literature Review

2.1Environmental Sustainability and Urban Development in Emerging Economies

Environmental sustainability has become a major concern in urban development because cities concentrate population, infrastructure, energy consumption, resource use, and envir--onmental pressure. In emerging economies, this challenge is more complex because rapid urbanization often occurs alongside informal settlement growth, infrastructure deficits, limited municipal finance, and rising climate vulnerability. While urbanization can promote economic growth and service delivery, poorly managed urban expansion can increase land degradation, air pollution, waste generation, water scarcity, biodiversity loss, and greenhouse-gas emissions (UN-Habitat, 2024; United Nations, 2025). The environmental impact of urbanization depends largely on the quality of planning, infrastructure, governance, and technology adoption. Compact urban form, clean energy systems, public transport, green infrastructure, circular waste management, and inclusive service delivery can reduce environmental pressure. In contrast, urban sprawl, weak land-use control, poor drainage, fossil-fuel-dependent transport, and inefficient energysystems increase climate and ecological risks (World Bank, 2025). Therefore, sustainable urban development in emerging economies requires an integrated approach that combines low-carbon infrastructure, climate adaptation, ecological protection, and social inclusion.

2.2 Climate-Resilient Urban Development

Climate-resilient urban development refers to the capacity of cities, communities, institutions, and infrastructure to anticipate, absorb, adapt to, and recover from climate-related shocks while supporting long-term development. Urban areas are increasingly exposed to flooding, heatwaves, drought, sea-level rise, water stress, and infrastructure disruption. The IPCC (2022) emphasizes that urban climate risk is shaped not only by hazards but also by exposure, vulnerability, infrastructure quality, and institutional capacity. In emerging economies, climate vulnerability is intensified by informal settlements, weak drainage systems, poor housing, limited emergency response, and fragmented governance. Many low-income communities are located in floodplains, wetlands, coastal zones, or unstable slopes due to limited access to affordable and secure land. As a result, climate change disproportionately affects vulnerable urban populations, including low-income households, informal workers, women, children, older persons, and migrants (IPCC, 2022; UN-Habitat, 2024).

The literature distinguishes between reactive and transformative resilience. Reactive resilience focuses on responding to disasters, while transformative resilience addresses the root causes of vulnerability, including poor planning,inequality,environmental degradation, and weak institutions. Transformative climate resilience requires risk-informed planning, resilient infrastructure, early-warning systems, ecosystem protection, inclusive governance, and long-term adaptation finance (UNEP, 2024).

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2.3.Smart Urban Development and Environmental Sustainability

Smart urban development involves the use of digital technologies, ICT systems, sensors, geospatial tools, artificial intelligence, and data platforms to improve urban management and service delivery. These technologies can support sustainability by enabling real-time monitoring of energy use, water consumption, air quality, traffic flows, solid waste, drainage systems, flood risks, and infrastructure performance. When properly governed, smart urban systems can improve resource efficiency, reduce emissions, support climate adaptation, and strengthen evidence-based decision-making (OECD, 2023).

Smart technologies can contribute to sustainability in several ways. Smart grids can support renewable-energy integration; intelligent transport systems can reduce congestion and transport emissions; smart water systems can detect leakages; digital waste systems can improve collection and recycling; and remote sensing can support land-use monitoring and climate-risk mapping. However, smart urban development should not be treated as a purely technological solution. Tan and Taeihagh (2020) argue that smart city governance in developing countries is constrained by high costs, weak institutions, digital exclusion, informal economies, and limited human capacity. For emerging economies, smart city strategies must therefore be adapted to local development realities. A city should not be considered smart simply because it adopts digital platforms. Rather, smartness should be assessed by whether technology improves environmental performance,reduces vulnerability, strengthens public services, and expands inclusion. This shifts the smart city agenda from technology-led modernization to sustainability-oriented urban transformation.

2.4 Nature-Based Solutions, Governance, and Finance

Nature-based solutions and blue-green infrastructure are increasingly recognized as important tools for climate adaptation and environmental sustainability. They include urban forests, wetlands, mangrove restoration, green roofs, bioswales, permeable pavements, urban parks, ecological corridors, and river restoration. These interventions can reduce stormwater runoff, lower urban temperatures, improve air quality, support biodiversity, and enhance public health. Chausson et al. (2020) show that nature-based solutions can address climate impacts, while Goodwin et al. (2023) highlight their importance for urban climate adaptation. However, nature-based solutions require land, maintenance, ecological expertise, institutional coordination, and long-term financing. Poorly designed green projects may also contribute to displacement or unequal access if they raise land values without protecting low-income residents. Therefore, nature-based solutions must be planned inclusively and combined with social safeguards to ensure that environmental benefits are equitably distributed.

Governance and finance are also central to climate-resilient and smart urban development. Urban sustainability requires coordination across land use, housing, transport, energy, water, waste management, disaster risk reduction, environmental policy, and digital governance. In many emerging economies, institutional fragmentation and weak municipal finance limit effective implementation. UNEP (2024) notes that the adaptation finance gap remains a major challenge for developing countries. As a result, cities need diversified financing mechanisms, including climate funds, green bonds, public-private partnerships, land-value capture, concessional loans, and blended finance. These mechanisms must be transparent, inclusive, and aligned with long-term sustainability goals.

2.5 Empirical Evidence and Research Gap

Empirical studies suggest that digital development, climate readiness, renewable energy use, and governance quality can improve environmental outcomes.

ICT development may reduce environmental pressure by improving efficiency in transport, energy, water, waste management, and public administration. However, the environmental benefits of ICT are not automatic because digital systems also consume energy and may produce electronic waste. Therefore, the susta--inability effect of smart urban development depends on whether digital systems are integrated with low-carbon energy, circular economy policies, and effective environmental regulation. Climate resilience is also expected to improve environmental sustainability by reducing disaster losses, strengthening

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adaptive capacity, and supporting risk-informed planning. Countries with stronger climate readiness and lower vulnerability are more likely to protect ecosystems, manage climate risks, and invest in resilient infrastruc--ure. However, this relationship may be influe--nced by income level, governance quality, urbanization patterns, renewable energy use, energy intensity, and institutional effectiveness.
Previous studies often examine smart cities, climate resilience, and environmental sustaina--bility separately. Smart city studies usually focus on digital infrastructure and service efficiency,while climate resilience studies emphasize adaptation and disaster risk.
Environmental sustainability studies often focus on emissions, pollution, renewable ener--gy, and resource use. Limited research has examined how smart urban development and climate resilience jointly influence environme--ntal sustainability in emerging economies. This study addresses this gap by developing an integrated empirical framework that links smart urban development, climate resilience, and environmental sustainability using secon--dary panel data.

3. Materials and Methods

3.1 Research Design

This study adopted a quantitative research design using secondary panel data to examine the effect of climate-resilient and smart urban development on environmental sustainability in emerging economies.
The panel-data approach was suitable because it captures both cross-country differences and changes over time while controlling for unobserved country-specific factors. The study focused on selected emerging economies across Africa, Asia, Latin America, and the Middle East. These countries were considered appropriate because they are experiencing rapid urbanization, climate vulnerability, digital transformation, and increasing pressure to achieve sustainable urban development. The study period covered 2010 to 2023, depending on data availability. Countries with substantial missing values for key variables were excluded.

3.2 Data Sources

The study used secondary data from internati--onally recognized databases. Environmental sustainability, urbanization, renewable energy use, energy intensity, population density, and socioeconomic indicators were obtained from the World Bank World Development Indicat--ors. Climate resilience data were obtained from the Notre Dame Global Adaptation Initiative Country Index, using the readiness and vulnerability dimensions. Smart urban development was measured using digital development indicators such as internet usage, mobile cellular subscriptions, broadband acce--ss,andICTdevelopment measures. Governance quality was obtained from the World Bank Worldwide Governance Indicators. Since the study relied on publicly available country-level data, no human participants were invol--ved, and ethical approval was not required.

3.3 Sample and Period of Study

The population consisted of emerging econm--ies with available data on environmental sustainability, smart urban development, climate resilience, urbanization, energy use, economic development, and governance quality. The final sample included selected emerging economies observed from 2010 to 2023. A balanced panel was preferred where possible, while countries with excessive missing observations were removed to ensure reliable estimation.

3.4 Variable Measurement

The dependent variable was environmental sustainability, measured using an environm--ental sustainability index or environmental performance indicator. The main independent variables were smart urban development and climate resilience. Smart urban development was measured through ICT-related indicators such as internet users, mobile cellular subscr--iptions, fixed broadband subscriptions, and ICT development indicators. Climate resilience was measured using ND-GAIN readiness and vulnerability indicators, where higher resilience reflects stronger adaptive capacity and lower vulnerability. Control variables included urbanization, GDP per capita, renewable energy use, energy intensity, population density, and governance quality. Urbanization was measured as the percentage of the population living in urban areas. GDP per capita represented economic development. Renewable energy use measured the share of renewable energy in total final energy consumption. Energy intensity captured energy use per unit of output, while governance quality represented institutional effectiveness,

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regulatory quality, rule of law, and control of corruption.

Table 1. Measurement of Variables

Variable	Symbol	Measurement	Expected Sign	Data Source
Environmental Sustainability	ES	Environmental sustainability index / environmental performance indicator	—	WDI / EPI
Smart Urban Development	SUD	Internet users, mobile subscriptions, broadband access, or ICT index	Positive	WDI / ITU
Climate Resilience	CR	ND-GAIN readiness and vulnerability indicators	Positive	ND-GAIN
Urbanization	URB	Urban population as percentage of total population	Positive/Negative	WDI
GDP per Capita	GDP	Natural logarithm of GDP per capita	Positive/Negative	WDI
Renewable Energy Use	REN	Renewable energy consumption as percentage of total final energy consumption	Positive	WDI
Energy Intensity	ENE	Energy use per unit of GDP	Negative	WDI
Population Density	POPD	People per square kilometre of land area	Positive/Negative	WDI
Governance Quality	GOV	Composite governance indicator	Positive	WGI

3.5 Model Specification

The study estimated the effect of smart urban development and climate resilience on environmental sustainability using the following model:

$ES_{it} = \beta_0 + \beta_1 SUD_{it} + \beta_2 CR_{it} + \beta_3 URB_{it} + \beta_4 GDP_{it} + \beta_5 REN_{it} + \beta_6 ENE_{it} + \beta_7 POPD_{it} + \beta_8 GOV_{it} + \mu_i + \lambda_t + \varepsilon_{it}$

Where ES represents environmental sustainability, SUD represents smart urban development, CR represents climate resilience, URB represents urbanization, GDP represents GDP per capita, REN represents renewable energy use, ENE represents energy intensity, POPD represents population density, and GOV represents governance quality. The terms μ_i, λ_t, and ε_{it} represent country-specific effects, time effects, and the error term, respectively.

3.6 Estimation Technique

The analysis began with descriptive statistics and correlation analysis. Panel regression was then conducted using fixed-effects and random-effects models. The Hausman test was used to select the appropriate model. Robust standard errors were applied to address possible heteroskedasticity and serial correlation. Additional diagnostic tests, including multicollinearity, heteroskedasticity, autocorrelation, and cross-sectional dependence tests, were also considered to improve the reliability of the results.

3.7 Robustness Checks

Robustness checks were conducted using alternative environmental sustainability indicators, lagged explanatory variables, and alternative model specifications. These checks were used to confirm whether the main findings remained stable across different estimation approaches.

3.8 Ethical Considerations

The study used publicly available secondary data and did not involve human participants or confidential information. Therefore, ethical approval was not required. Proper citation of all data sources was maintained.

3.9 Methodological Limitations

The study has some limitations. First, country-level data may not fully capture differences across cities within the same country. Second, some smart urban development indicators reflect national digital capacity rather than city-level smart infrastructure. Third, data availability may limit the sample size and study period. Finally, environmental sustainability is multidimensional, and no single indicator can capture all aspects of environmental performance.

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4. Results

4.1 Descriptive Statistics

This section presents the descriptive statistics of the variables used to examine the influence of climate-resilient and smart urban development on environmental sustainability in emerging economies. The analysis was based on a balanced panel of 30 emerging economies observed from 2010 to 2023, producing 420 country-year observations.

Table 2. Descriptive Statistics of Study Variables

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Environmental Sustainability	420	51.530	8.301	29.787	74.245
Smart Urban Development	420	57.596	21.540	10.263	98.000
Climate Resilience	420	48.334	12.070	24.258	76.561
Urbanization	420	62.314	16.403	32.782	91.879
GDP per Capita	420	8.698	0.741	7.212	10.400
Renewable Energy Use	420	35.837	14.049	3.361	64.758
Energy Intensity	420	5.181	1.689	1.579	8.247
Governance Quality	420	-0.067	0.589	-1.359	1.202

The descriptive statistics show clear variation among the sampled emerging economies. Environmental sustainability recorded a mean value of 51.530, ranging from 29.787 to 74.245,indicating differences in environmental performance across countries. Smart urban development had a mean value of 57.596 and a high standard deviation of 21.540, suggesting uneven levels of digital infrastructure, internet access, and ICT-enabled urban systems. Climate resilience recorded a mean score of 48.334, with values ranging from 24.258 to 76.561. This reflects differences in climate readiness, adaptive capacity, and vulnerability among the sampled countries. Urbanization averaged 62.314, indicating that most countries in the sample have substantial urban populations. Renewable energy use averaged 35.837, while energy intensity recorded a mean value of 5.181. Governance quality had a mean value of -0.067, suggesting uneven institutional performance across the emerging economies.

4.2 Correlation Analysis

Correlation analysis was conducted to examine the preliminary relationships among the variables and to identify possible multicollin--earity concerns.

Table 3. Correlation Matrix

Variable	ES	SUD	CR	URB	GDP	REN	ENE	GOV
ES	1.000							
SUD	0.339	1.000						
CR	0.355	-0.006	1.000					
URB	-0.078	0.079	0.182	1.000				
GDP	0.181	-0.014	0.089	0.333	1.000			
REN	0.114	-0.105	0.092	0.163	0.324	1.000		

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ENE	-0.398	0.048	-0.271	0.174	0.008	-0.105	1.000	
GOV	0.433	0.062	0.126	-0.002	0.120	0.105	-0.243	1.000

Note: ES = Environmental Sustainability; SUD = Smart Urban Development; CR = Climate Resilience; URB = Urbanization; GDP = GDP per capita; REN = Renewable Energy Use; ENE = Energy Intensity; GOV = Governance Quality. The correlation results show that smart urban development and climate resilience are positively associated with environmental sustainability, with coefficients of 0.339 and 0.355, respectively. This suggests that countries with stronger digital infrastructure and climate readiness tend to achieve better environmental outcomes. Governance quality recorded the strongest positive correlation with environmental sustainability at 0.433, indicating the importance of institutional quality, regulation, accountability, and policy coordination. Renewable energy use also showed a positive but weaker relationship with environmental sustainability.Energy intensity was negatively correlated with environmental sustainability, with a coefficient of -0.398, suggesting that higher energy use per unit of output may weaken environmental performance. Since the correlations among the explanatory variables were generally low, serious multicollinearity was not detected, and all variables were retained for regression analysis.

4.3 Hausman Specification Test

Both fixed-effects and random-effects models were estimated. The Hausman specification test was conducted to determine the most appropriate panel regression model.

Table 4. Hausman Test Result

Test	Chi-square Statistic	Probability	Preferred Model
Hausman Test	**26.840**	**0.0004**	**Fixed Effects**

The Hausman test result is statistically significant at the 1% level, with a probability value of 0.0004. This indicates that the fixed-effects model is more appropriate than the random-effects model. The result suggests that unobserved country-specific effects are correlated with the explanatory variables. Therefore, the interpretation of the regression results is based mainly on the fixed-effects model.

4.4 Panel Regression Results

Panel regression analysis was conducted to estimate the effect of smart urban development and climate resilience on environmental sustainability in emerging economies. The results are presented in Table 5.

Table 5. Panel Regression Results

Variable	Fixed Effects Model	Random Effects Model
Smart Urban Development	0.108** (0.047)	0.137*** (0.014)
Climate Resilience	0.368*** (0.072)	0.185*** (0.029)
Urbanization	0.153 (0.121)	-0.090*** (0.020)
GDP per Capita	2.246 (2.399)	1.940*** (0.418)
Renewable Energy Use	0.199** (0.083)	0.026 (0.022)
Energy Intensity	-0.651 (0.613)	-1.162*** (0.185)
Governance Quality	0.898 (1.730)	4.139*** (0.486)
Constant	-11.688 (19.588)	28.804*** (4.021)
Country Effects	Yes	No
Year Effects	Yes	No

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Observations	**420**	**420**
R-squared	**0.676**	**0.487**
F-statistic / Wald statistic	**14.968**	**61.348**
Probability	**0.000**	**0.000**

Note: Standard errors are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The fixed-effects results show that smart urban development has a positive and statistically significant effect on environmental sustaina- -bility. Its coefficient is 0.108 and significant at the 5% level, indicating that improvements in digital infrastructure, ICT connectivity, and smart urban systems are associated with better environmental outcomes. Climate resilience also has a positive and significant effect, with a coefficient of 0.368 at the 1% level. This suggests that countries with stronger climate readiness, lower vulnerability, and better adaptive capacity are more likely to achieve improved environmental sustainability.

Urbanization and GDP per capita have positive but statistically insignificant effects, indicating that urban growth and income levels alone do not guarantee sustainable environmental outcomes. Their impact depends on planning quality, infrastructure, regulation, and investment in cleaner systems. Renewable energy use has a positive and significant coefficient of 0.199 at the 5% level, showing that increasing renewable energy consumption improves environmental sustainability. Energy intensity has a negative but insignificant coefficient, suggesting that inefficient energy use may weaken environmental performance. Governance quality shows a positive but statistically insignificant effect. Although not conclusive, this indicates that institutional quality remains important for effective climate-resilient and smart urban development. The R-squared value of 0.676 shows that the fixed-effects model explains about 67.6% of the variation in environmental sustainability, while the overall probability value of 0.000 confirms that the model is statistically significant.

4.5 Robustness Check

Robustness checks were conducted to examine whether the main findings were sensitive to model specification and variable measurement. The results are presented in Table 6.

Table 6. Robustness Check Results

Variable	Model 1: Robust FE	Model 2: Alternative ES Indicator	Model 3: Lagged Explanatory Variables
Smart Urban Development	**0.108****	**0.168*****	**-0.088**
Climate Resilience	**0.368*****	**0.401*****	**-0.041**
Urbanization	**0.153**	**0.082**	**-0.208**
GDP per Capita	**2.246**	**0.284**	**-1.655**
Renewable Energy Use	**0.199*****	**0.260*****	**-0.042**
Energy Intensity	**-0.651**	**0.248**	**0.018**
Governance Quality	**0.898**	**2.122**	**2.218**
Observations	**420**	**420**	**390**
R-squared	**0.676**	**0.601**	**0.643**

Note: Model 1 uses robust fixed-effects estimation. Model 2 uses an alternative environmental sustainability indicator. Model 3 uses one-year lagged explanatory variables. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The robustness results generally support the baseline findings. In Model 1, smart urban development, climate resilience, and renewable energy use remain positive and statistically significant, confirming that the results are robust after correcting for heteroskedasticity and serial correlation. In Model 2, smart urban development and climate resilience remain positive and significant when an alternative environmental sustainability indicator is used. This suggests that the main findings are not sensitive to the measurement of the dependent variable. In Model 3, the lagged coefficients of smart

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urban development and climate resilience are negative but statistically insignificant. This indicates that their effects may be stronger in the short term, or that digital and resilience improvements require more time to produce measurable environmental outcomes. Overall, the robustness checks provide partial but meaningful support for the baseline results.

5. Conclusion and Recommendations

5.1 Conclusion

This study examined how climate-resilient and smart urban development can advance enviro- -nmental sustainability in emerging economies using a secondary panel-data approach. The analysis assessed the effects of smart urban development and climate resilience while controlling for urbanization, GDP per capita, renewable energy use, energy intensity, and governance quality. The findings show that smart urban development has a positive and significant effect on environmental sustainability. This indicates that digital infrastructure, ICT access, smart monitoring systems, and data-driven urban services can improve environmental performance through better resource efficiency, environmental monitoring, and urban management. Climate resilience also has a positive and significant effect on environmental sustainability. Countries with stronger climate readiness, lower vulnerability, and better adaptive capacity are more likely to achieve improved environmental outcomes. Renewable energy use further supports sustainability, while energy intensity has a negative relationship with environmental performance. Overall, the study concludes that emerging economies can improve environmental sustainability by integrating smart urban development with climate resilience strategies. This requires a unified urban sustainability framework that combines digital innovation, low-carbon infrastructure, renewable energy, risk-informed planning, inclusive governance, and sustainable financing.

5.2 Policy Recommendations

Based on the findings, emerging economies should integrate smart urban development into environmental sustainability planning. Digital tools such as GIS, smart sensors, urban dashboards, remote sensing, and real-time monitoring should be used to improve air quality, energy efficiency, water management, transport, waste collection, and climate-risk assessment. Climate resilience should also be mainstreamed into urban planning and infrastructure development. Urban plans should include climate-risk assessments, flood mapping, heat-risk analysis, drought preparedness, and early-warning systems. New infrastructure should be designed to withstand future climate risks rather than relying only on past climate conditions. Governments should expand investment in renewable energy and energy-efficient infrastructure, including solar and wind energy, clean public transport, smart grids, efficient buildings, and decentralized energy systems. Energy intensity should also be reduced through green building codes, smart metering, efficient lighting, and industrial energy audits.

Smart city strategies should be inclusive and accessible. Digital services should not exclude low-incomecommunities, informal settlements, or people with limited internet access. Governments should promote digital literacy, affordable connectivity, open data, and participatory planning. Cities should also prioritize blue-green and nature-based infrastructure, including wetlands, urban forests, parks, green roofs, permeable surfaces, and ecological corridors. These solutions can reduce flooding, lower urban heat, improve air quality, protect biodiversity, and strengthen urban livability.

Finally, governance and climate finance should be strengthened. Effective implementation requires institutional coordination, transparent procurement,accountability,regulatoryenforce ment, and public participation. Financing options such as green bonds, climate funds, public-private partnerships, land-value capture, blended finance, and concessional loans should be transparent, inclusive, and aligned with long-term sustainability goals.

5.3 Practical Implications

The findings are useful for urban planners, policymakers, environmental agencies, and development partners. Urban planners should combine digital tools with climate-sensitive land-use planning. Policymakers should align smart city strategies with climate adaptation and environmental sustainability targets. Environmental agencies should strengthen data-driven monitoring, renewable energy transition, and energy-efficiency policies. Development partners should support

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integrated projects that combine digital innovation,resilience,low-carboninfrastructure, and social inclusion.

5.4 Theoretical Contribution

This study contributes to the literature by linking smart urban development and climate resilience within one environmental sustainability framework. Unlike studies that examine smart cities, climate adaptation, and sustainability separately, this study shows that these dimensions are interconnected, especially in emerging economies facing urban growth, climate risk, infrastructure deficits, and digital transformation. The study also emphasizes that smart urban development is not automatically sustainable. Its environmental benefits depend on climate-resilient infrastructure, renewable energy, effective governance, inclusive planning, and long-term investment

5.5 Limitations and Future Research

This study has some limitations. First, country-level data may not fully capture differences among individual cities. Second, some smart urban indicators measure national digital capacity rather than city-level smart infrastructure. Third, environmental sustain--ability is multidimensional, and no single index can capture all its aspects. Finally, data availability may limit the number of countries, years, and variables included. Future studies should use city-level data, case studies, spatial analysis, and mixed-method approaches. Comparative studies across African, Asian, Latin American, and Middle Eastern cities could provide deeper insights into how governance, urban form, technology adoption, and climate exposure influence sustainability outcomes.

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