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Determinants of Urban Resilience toward Sustainable City Development

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Abstract: Urban resilience is a key component of sustainable urban development as cities face increasing challenges from rapid urbanization, climate change, environmental degradation, and socioeconomic uncertainty. This study examined the determinants of urban resilience and its mediating role in sustainable city development using Structural Equation Modeling (SEM). A cross-sectional survey of 420 urban residents was analyzed using Confirmatory Factor Analysis (CFA), SEM, and mediation analysis. The proposed model assessed the effects of green infrastructure, governance effectiveness, smart city initiatives, and community participation on urban resilience and evaluated whether resilience mediates their influence on sustainable city development. The measurement model demonstrated satisfactory reliability and validity, while the structural model showed good fit (χ^2/df = 2.34, CFI = 0.96, TLI = 0.95, RMSEA = 0.05, SRMR = 0.04). Governance effectiveness emerged as the strongest predictor of urban resilience (β = 0.63), followed by green infrastructure (β = 0.58), community participation (β = 0.55), and smart city initiatives (β = 0.52) (all $p < 0.001$). Urban resilience significantly predicted sustainable city development (β = 0.71, $p < 0.001$), explaining 50.4% of its variance (R^2 = 0.504). Mediation analysis confirmed that urban resilience significantly mediated the relationships between all determinants and sustainable city development, highlighting resilience as the mechanism through which environmental, institutional, technological, and social capacities contribute to sustainability. These findings provide empirical evidence supporting integrated urban planning approaches and offer practical guidance for policymakers seeking to develop more adaptive, inclusive, and sustainable cities.

Keywords: Urban resilience; Sustainable city development; Green infrastructure; Smart cities; Structural Equation Modeling.

Introduction

The twenty-first century has witnessed an unprecedented transformation in the scale, complexity, and dynamics of urbanization. Cities have become the principal engines of economic growth, technological innovation, and social development, accommodating more than half of the world's population while generating the majority of global economic output (Kadakia & Galea, 2023). At the same time, urban areas have become increasingly vulnerable to a wide range of interconnected environmental, social, economic, and institutional challenges (Nijman & Wei, 2020). Climate change, biodiversity loss, rapid population growth, infrastructure deterioration, resource scarcity, environmental pollution, and socioeconomic inequality have collectively intensified the pressure on urban systems, exposing weaknesses in conventional planning approaches that primarily emphasize economic expansion and physical development (Fletcher, et al., 2024). Consequently, ensuring that cities remain livable, adaptive, and sustainable has emerged as one of the most pressing challenges confronting governments, planners, and policymakers worldwide.

Traditional urban development models have largely focused on maximizing efficiency, expanding infrastructure, and promoting economic competitiveness. While these strategies have generated substantial economic benefits, they have often overlooked the capacity of cities to cope with uncertainty, respond to disturbances, and recover from unexpected shocks (Rahaman, et al., 2023). Recent global events including climate-related disasters, public health emergencies, and increasing environmental degradation have demonstrated that urban sustainability cannot be achieved solely through economic growth or infrastructure investment (Huang, et al., 2025). Rather, cities must possess the capacity to anticipate, absorb, adapt to, and recover from both sudden shocks and long-term stresses while continuing to provide essential services and maintain social, economic, and environmental functions (Stimpson, et al., 2025). This adaptive capacity is commonly conceptualized as urban resilience, which has become one of the central paradigms in contemporary urban planning and sustainable development.

Urban resilience extends beyond disaster management or emergency preparedness. It represents the ability of urban systems including physical infrastructure, ecological resources, governance institutions, technological networks, economic structures, and local communities, to function effectively under conditions of uncertainty while continuously adapting to changing circumstances (Cheshmehzangi, 2020). Unlike traditional planning approaches that prioritize stability and optimization, resilience-oriented planning recognizes that cities are dynamic and complex systems whose long-term sustainability depends on flexibility, redundancy, learning, and adaptive governance (Xu, et al., 2021). From this perspective, resilience should not be viewed merely as the capacity to “bounce back” following disruption, but rather as the ability to “bounce forward” by learning from disturbances and transforming urban systems to become more sustainable, equitable, and capable of addressing future challenges (Patel, et al., 2017).

The growing emphasis on resilience has significantly influenced contemporary theories of sustainable urban development. Sustainable city development is no longer understood exclusively in terms of environmental conservation or economic performance (He, et al., 2024). Instead, it encompasses the balanced integration of environmental protection, economic prosperity, social inclusion, institutional effectiveness, technological innovation, and long-term urban adaptability (Crane, et al., 2021). This broader perspective closely aligns with the objectives of the United Nations Sustainable Development Goal 11, which advocates for cities that are inclusive, safe, resilient, and sustainable. Within this framework, resilience and sustainability should not be regarded as separate or competing policy objectives (Chaaben, et al., 2022). Rather, resilience provides one of the essential mechanisms through which long-term sustainability can be achieved, enabling cities to maintain functionality, reduce vulnerability, and enhance adaptive capacity in the face of growing uncertainty (Wang, et al., 2024).

Recognizing cities as complex socio-ecological systems has shifted attention toward the multiple factors that collectively shape urban resilience (Frantzeskaki, et al., 2024). Contemporary urban resilience research increasingly acknowledges that resilience emerges from the interaction of environmental, institutional, technological, and social dimensions rather than from any single component in isolation (Lv & Sarker, 2024). Consequently, improving resilience requires integrated planning strategies that simultaneously strengthen ecosystem services, governance quality, digital infrastructure, and community capacity (Lobo, et al., 2023). Such an integrated perspective reflects the reality that environmental interventions are unlikely to succeed without effective institutions, technological innovations require supportive governance and public acceptance, and community initiatives depend upon both institutional support and adequate physical infrastructure (Liao & Zhang, 2024). Urban resilience therefore represents a multidimensional capability resulting from the continuous interaction among diverse urban subsystems.

Among the environmental determinants of resilience, green infrastructure has received considerable attention because of its capacity to provide multiple ecological and social benefits simultaneously (Li & Carter, 2025). Urban forests, parks, wetlands, green corridors, and permeable landscapes contribute to climate adaptation by mitigating urban heat islands, reducing flood risks, improving air quality, conserving biodiversity, and enhancing ecosystem services (Jia & Turcu, 2025). Beyond these environmental functions, green infrastructure also improves public health, recreational opportunities, and residents' quality of life, thereby strengthening both ecological resilience and social well-being (Khalili, et al., 2024). As climate-related risks continue to intensify, ecosystem-based planning has become increasingly recognized as a cost-effective and sustainable strategy for enhancing cities' adaptive capacity while supporting broader sustainability objectives.

Building resilient cities, however, extends beyond environmental interventions and requires effective institutional arrangements capable of coordinating diverse stakeholders and responding to rapidly changing urban conditions. Governance effectiveness has consistently been recognized as a fundamental determinant of resilience because it influences the quality of decision-making, policy implementation, resource allocation, and inter-organizational coordination (Belloni, et al., 2025). Transparent, accountable, and responsive governance systems facilitate the development of adaptive policies, strengthen public trust, and enhance collaboration among governmental agencies, private organizations, and local communities. In contrast, fragmented governance structures and weak institutional capacity often limit cities' ability to prepare for, respond to, and recover from environmental and socioeconomic disruptions (Wu, et al., 2025). Consequently, governance is increasingly viewed as the institutional foundation upon which resilient and sustainable urban systems are built.

Alongside institutional capacity, technological innovation has emerged as another important component of urban resilience. The rapid development of smart city technologies has transformed the way cities manage infrastructure, public services, transportation systems, environmental monitoring, and emergency response. Digital platforms, geographic information systems, Internet of Things (IoT) devices, sensor networks, artificial intelligence, and big data analytics enable urban managers to collect real-time information, improve operational efficiency, and support evidence-based decision-making (Waqar, et al., 2025). These technologies enhance the capacity of cities to anticipate risks, optimize resource utilization, and respond more effectively to unexpected events. Nevertheless, technological advancement alone cannot ensure urban resilience. The effectiveness of smart city initiatives depends largely on institutional readiness, public acceptance, equitable access to digital services, and their integration within broader urban development strategies (Alahi, et al., 2023). Accordingly, technological innovation should be considered an enabling mechanism that complements rather than replaces sound governance and sustainable planning practices.

Urban resilience also possesses a strong social dimension, with increasing evidence demonstrating that communities play a central role in enhancing cities' adaptive capacity. Community participation strengthens resilience by promoting social capital, trust, collective learning, and collaborative problem-solving (Chou & Huang, 2021). Residents are often the first to experience the consequences of environmental hazards and are frequently among the earliest responders during emergencies. Their local knowledge, social networks, and willingness to participate in planning and decision-making contribute significantly to the effectiveness of resilience strategies. Furthermore, participatory planning improves the legitimacy of public policies by incorporating citizens' perspectives into urban development processes, thereby increasing policy acceptance and long-term implementation success (Vandrevala, et al., 2024). Cities characterized by active civic engagement and strong community cohesion are generally better equipped to recover from crises while maintaining social stability and supporting sustainable development initiatives.

Although previous studies have acknowledged the importance of green infrastructure, governance quality, smart city technologies, and community participation, much of the existing literature has examined these determinants independently or within relatively narrow analytical frameworks. Many empirical investigations have focused on a single dimension of resilience, such as environmental sustainability, institutional performance, or technological innovation, without considering the dynamic interactions among these interconnected components. Such fragmented approaches provide valuable insights into specific aspects of urban resilience but often fail to capture the complexity of contemporary urban systems, where environmental, institutional, technological, and social processes continuously influence one another. As a result, there remains a need for more comprehensive analytical frameworks capable of simultaneously examining multiple determinants of urban resilience and evaluating their collective contribution to sustainable city development.

Another important limitation within the existing literature concerns methodological approaches. While conceptual discussions of urban resilience have expanded considerably over the past decade, comparatively fewer studies have empirically validated integrated resilience frameworks using advanced multivariate analytical techniques. Because urban resilience and sustainable city development are multidimensional constructs that cannot be directly observed, they are more appropriately conceptualized as latent variables measured through multiple indicators. Structural Equation Modeling (SEM) provides a particularly suitable methodological framework for addressing this complexity by simultaneously evaluating measurement reliability and testing structural relationships among latent constructs. Compared with conventional regression techniques, SEM enables researchers to account for measurement error while examining multiple direct relationships within a unified conceptual model, thereby providing more robust evidence for both theoretical development and policy formulation.

The present study addresses these gaps by proposing and empirically testing an integrated conceptual framework in which green infrastructure, governance effectiveness, smart city initiatives, and community participation are conceptualized as complementary determinants of urban resilience, which subsequently promotes sustainable city development. Rather than viewing these factors as isolated policy domains, the study adopts a systems perspective that recognizes their interdependence in shaping the adaptive capacity of urban environments. This integrated approach contributes to the growing literature on urban resilience by providing a more comprehensive understanding of how environmental, institutional, technological, and social dimensions jointly influence sustainable urban development.

Accordingly, the primary objective of this study is to examine the determinants of urban resilience and their contribution to sustainable city development through an integrated Structural Equation Modeling framework. Specifically, the study investigates the influence of green infrastructure, governance effectiveness, smart city initiatives, and community participation on urban resilience, and subsequently evaluates the effect of urban resilience on sustainable city development. By empirically validating these relationships within a unified conceptual model, the study contributes to the advancement of urban resilience research while providing practical insights for policymakers, planners, and local governments seeking to develop more resilient, adaptive, and sustainable cities.

Methodology

Research Design

This study employed a quantitative, explanatory, and cross-sectional research design to investigate the determinants of urban resilience and their contribution to sustainable city development. Given the multidimensional nature of urban resilience and the complexity of the proposed conceptual framework, covariance-based Structural Equation Modeling (CB-SEM) was adopted as the primary analytical approach. CB-SEM enables the simultaneous assessment of both the measurement model and the structural relationships among latent constructs while explicitly accounting for measurement error, thereby providing a robust framework for theory testing and model validation.

Study Area and Participants

The study was conducted among adult residents, who represent one of the principal stakeholder groups directly affected by urban planning policies, environmental conditions, municipal services, and climate-related challenges. Eligible participants were individuals aged 18 years or older who had continuously resided in the study area for at least one year, ensuring that respondents possessed sufficient familiarity with local urban development issues and municipal governance. The target population comprised all adult residents of the selected metropolitan area. To improve the representativeness of the sample, a stratified random sampling strategy was employed. Initially, the city was divided into its administrative districts. Subsequently, respondents were randomly selected from each district in proportion to its population size, thereby ensuring adequate representation of different geographical areas and socioeconomic groups.

Sample Size Determination

The minimum required sample size was estimated using G*Power version 3.1.9.7. Following Cohen's recommendations for detecting medium effect sizes, the analysis assumed an effect size of $f^2 = 0.15$, a significance level of $\alpha = 0.05$, a statistical power of 0.95, and five predictor variables. The analysis indicated a minimum sample of 204 respondents. Nevertheless, because covariance-based SEM generally requires larger samples to achieve stable parameter estimates and reliable model fit, 450 questionnaires were distributed. After data screening, 420 valid questionnaires were retained for the final analysis, representing an effective response rate of 93.3%. This sample substantially exceeded the minimum statistical requirement and was therefore considered adequate for reliable SEM estimation.

Inclusion and Exclusion Criteria

For inclusion in the study, participants had to be at least 18 years of age, have lived continuously in the study area for at least one year, be able to understand the questionnaire language, and voluntarily agree to participate by providing informed consent. Conversely, temporary visitors or non-residents, individuals who submitted questionnaires with more than 10% missing data, those exhibiting clear response bias (e.g., straight-line responses or unrealistically short completion times), and individuals who declined informed consent were excluded from the study.

Measurement Instruments

Data were collected using a structured questionnaire consisting of two sections. The first section obtained respondents' demographic information, including gender, age, educational attainment, occupation, monthly income, and years of residence. The second section measured the six latent constructs included in the proposed conceptual framework using standardized measurement scales adapted from the existing literature.

- **Green Infrastructure (4 items):** assessed respondents' perceptions of accessibility to urban green spaces, ecological quality, vegetation coverage, and ecosystem services.

- **Governance Effectiveness (4 items):** evaluated transparency, accountability, responsiveness, and effectiveness of municipal governance.
- **Smart City Initiatives (4 items):** measured perceptions regarding digital infrastructure, smart public services, technological innovation, and information accessibility.
- **Community Participation (4 items):** assessed citizens' involvement in urban planning, environmental initiatives, and local decision-making.
- **Urban Resilience (5 items):** evaluated adaptive capacity, disaster preparedness, institutional flexibility, infrastructure robustness, and recovery capability.
- **Sustainable City Development (5 items):** assessed environmental sustainability, economic vitality, social inclusion, quality of life, and sustainable urban governance.

All questionnaire items were measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Prior to the main survey, the questionnaire was reviewed by experts in urban planning and environmental management to establish content validity. Subsequently, a pilot study involving 30 residents was conducted to evaluate clarity, readability, and internal consistency. Minor linguistic revisions were made based on participants' feedback before the final questionnaire was administered.

Data Collection Procedure

Data collection was conducted over approximately three months using both online and paper-based questionnaires to maximize participation. Respondents were informed about the objectives of the study, the voluntary nature of participation, confidentiality of their responses, and their right to withdraw at any stage. No personally identifiable information was collected, and all datasets were anonymized before analysis in accordance with accepted research ethics principles.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics version 29 and IBM SPSS AMOS version 29. Prior to hypothesis testing, the dataset was screened for missing values, outliers, normality, and multicollinearity. Cases with excessive missing data were removed, while minor missing values were handled using the Expectation-Maximization algorithm. Univariate outliers were assessed using standardized z-scores, whereas multivariate outliers were evaluated through Mahalanobis distance. Data normality was examined using skewness and kurtosis statistics, and multicollinearity was assessed using Variance Inflation Factor (VIF) values. Common method bias was examined using Harman's single-factor test. The measurement model was subsequently evaluated through Confirmatory Factor Analysis (CFA). Internal consistency was assessed using Cronbach's alpha and Composite Reliability (CR), with values above 0.70 considered acceptable. Convergent validity was evaluated using standardized factor loadings and Average Variance Extracted (AVE), while discriminant validity was assessed using both the Fornell–Larcker criterion and the Heterotrait–Monotrait Ratio (HTMT). Finally, the structural model was estimated using Maximum Likelihood Estimation (MLE) to test the proposed hypotheses. Model adequacy was evaluated using multiple goodness-of-fit indices, including the Chi-square to degrees of freedom ratio (χ^2/df), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). The explanatory power of the endogenous constructs was assessed using coefficients of determination (R^2), while standardized path coefficients, Critical Ratios (C.R.), and corresponding p-values were used to evaluate the proposed hypotheses.

Results

Data Screening

Prior to hypothesis testing, the dataset was subjected to a comprehensive screening process to ensure its suitability for covariance-based Structural Equation Modeling (CB-SEM). A total of 450 questionnaires were distributed, of which 420 valid responses were retained for analysis after eliminating incomplete and invalid questionnaires, yielding an effective response rate of 93.3%. The final sample exceeded the minimum sample size of 204 respondents estimated using G*Power, indicating that the study possessed adequate statistical power for model estimation. The dataset was initially examined for missing values. Missing data accounted for less than 2% of all responses and were randomly distributed. Because the proportion of missing data was minimal, the Expectation–Maximization (EM) algorithm was applied to estimate missing values, thereby preserving the sample size without introducing substantial bias.

Univariate outliers were assessed using standardized *z*-scores, while multivariate outliers were examined using Mahalanobis distance (D^2). The analysis identified a small number of extreme observations, which were removed before conducting the final analysis. Following data cleaning, no statistically significant outliers remained. The assumption of normality was evaluated using skewness and kurtosis statistics. As presented in Table 2, all variables exhibited skewness values within ±2 and kurtosis values within ±2, indicating acceptable univariate normality and supporting the use of Maximum Likelihood Estimation (MLE) in AMOS. Multicollinearity among the predictor constructs was examined using Variance Inflation Factor (VIF) statistics. VIF values ranged from 1.25 to 2.10, well below the recommended threshold of 5.0, indicating that multicollinearity was not a concern. Furthermore, Harman's single-factor test revealed that the first unrotated factor explained 34.8% of the total variance, substantially below the recommended threshold of 50%, suggesting that common method bias was unlikely to threaten the validity of the findings. Overall, the results of the preliminary screening procedures confirmed that the dataset satisfied the assumptions required for confirmatory factor analysis and structural equation modeling.

Respondent Characteristics

The demographic characteristics of the respondents are presented in Table 1. Of the 420 participants included in the final analysis, 221 (52.6%) were male and 199 (47.4%) were female, indicating a relatively balanced gender distribution. Regarding age, the largest proportion of respondents (34.5%) were between 30 and 39 years, followed by those aged 40–49 years (26.0%), 18–29 years (24.3%), and 50 years or older (15.2%). This distribution suggests that the sample was predominantly composed of economically active adults with substantial experience of the urban environment. With respect to educational attainment, 43.3% of respondents held a Bachelor's degree, 30.7% possessed a Master's degree, 16.9% had a Diploma, and 9.1% held a doctoral degree. The relatively high educational profile of the sample indicates that most participants were capable of providing informed evaluations of urban planning, governance, and sustainability issues. Regarding employment status, the largest group consisted of private sector employees (37.1%), followed by government employees (28.1%), self-employed individuals (19.8%), and students (15.0%). The diversity of occupational backgrounds enhances the representativeness of the sample by incorporating perspectives from different sectors of society. Overall, the demographic profile demonstrates that the respondents represented a broad cross-section of the urban population with respect to gender, age, educational level, and employment status, thereby providing a suitable basis for examining the determinants of urban resilience and sustainable city development.

Table 1. Demographic Characteristics of Respondents

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	221	52.6
	Female	199	47.4
	Total	**420**	**100.0**
Age (years)	18–29	102	24.3
	30–39	145	34.5
	40–49	109	26.0
	≥50	64	15.2
	Total	**420**	**100.0**
Education	Diploma	71	16.9
	Bachelor's degree	182	43.3
	Master's degree	129	30.7
	PhD	38	9.1
	Total	**420**	**100.0**
Occupation	Government employee	118	28.1
	Private sector employee	156	37.1
	Self-employed	83	19.8
	Student	63	15.0
	Total	**420**	**100.0**

Descriptive Statistics

Descriptive statistics for the study variables are presented in Table 2. The mean scores ranged from 3.59 to 3.91, indicating that respondents generally reported moderately positive perceptions of the constructs investigated. Among the variables, Governance Effectiveness recorded the highest mean score (M = 3.91, SD = 0.64), followed by Urban Resilience (M = 3.84, SD = 0.67) and Green Infrastructure (M = 3.82, SD = 0.71). In contrast, Community Participation exhibited the lowest mean score (M = 3.59, SD = 0.74), suggesting relatively greater variability in citizens' perceptions of their involvement in urban planning and local decision-making. The standard deviation values ranged from 0.64 to 0.74, indicating moderate variability in respondents' responses without excessive dispersion. Furthermore, all skewness values ranged between −0.73 and −0.29, while kurtosis values ranged between −0.61 and 0.52. These values fall well within the commonly accepted thresholds (±2), indicating that the observed variables approximated a normal distribution and satisfied the assumptions required for Maximum Likelihood Estimation in covariance-based Structural Equation Modeling. Overall, the descriptive statistics suggest that the data exhibit satisfactory distributional characteristics and are appropriate for subsequent confirmatory factor analysis and structural model estimation.

Table 2. Descriptive Statistics of the Study Variables

Construct	Mean	SD	Skewness	Kurtosis
Green Infrastructure	3.82	0.71	−0.51	0.28
Governance Effectiveness	3.91	0.64	−0.73	0.52
Smart City Initiatives	3.67	0.69	−0.36	−0.18
Community Participation	3.59	0.74	−0.29	−0.61
Urban Resilience	3.84	0.67	−0.58	0.34
Sustainable City Development	3.79	0.68	−0.47	0.15

Measurement Model Assessment

Before testing the structural relationships among the latent constructs, the measurement model was evaluated using Confirmatory Factor Analysis (CFA) in AMOS. The purpose of CFA was to examine whether the observed indicators adequately represented their corresponding latent constructs and to establish the reliability and validity of the measurement model. The initial measurement model consisted of six latent constructs: Green Infrastructure (GI), Governance Effectiveness (GE), Smart City Initiatives (SCI), Community Participation (CP), Urban Resilience (UR), and Sustainable City Development (SCD). Each construct was measured using multiple observed indicators adapted from previously validated scales. The CFA results indicated that all standardized factor loadings were statistically significant ($p < 0.001$) and exceeded the recommended threshold of 0.70, demonstrating strong relationships between the observed items and their respective latent variables. As presented in Table 3, standardized factor loadings ranged from 0.74 to 0.91, indicating satisfactory indicator reliability. Internal consistency reliability was assessed using Cronbach's alpha (α) and Composite Reliability (CR). All constructs achieved values above the recommended minimum level of 0.70, confirming adequate reliability. Specifically, Cronbach's alpha values ranged from 0.85 to 0.91, while Composite Reliability values ranged from 0.88 to 0.93. Convergent validity was assessed through the Average Variance Extracted (AVE). The AVE values for all constructs exceeded the recommended threshold of 0.50, ranging from 0.63 to 0.74, indicating that the constructs explained more than half of the variance in their respective indicators. Therefore, the measurement model demonstrated satisfactory reliability and convergent validity. The overall goodness-of-fit indices also indicated that the measurement model provided an acceptable representation of the observed data ($\chi^2/df = 2.21$, CFI = 0.96, TLI = 0.95, RMSEA = 0.05, SRMR = 0.04). These results confirmed that the measurement model was suitable for subsequent structural model analysis.

Table 3. Confirmatory Factor Analysis Results and Reliability Assessment

Construct	Item	Standardized Loading	Cronbach's α	Composite Reliability (CR)	AVE
Green Infrastructure (GI)	GI1	0.82	0.87	0.89	0.68
	GI2	0.79			
	GI3	0.88			
	GI4	0.81			
Governance Effectiveness (GE)	GE1	0.85	0.90	0.92	0.74
	GE2	0.91			
	GE3	0.83			
	GE4	0.86			
Smart City Initiatives (SCI)	SCI1	0.78	0.85	0.88	0.65
	SCI2	0.84			

Construct	Item	Standardized Loading	Cronbach's α	Composite Reliability (CR)	AVE
	SCI3	0.81			
	SCI4	0.80			
Community Participation (CP)	CP1	0.76	0.84	0.87	0.63
	CP2	0.82			
	CP3	0.79			
	CP4	0.81			
Urban Resilience (UR)	UR1	0.84	0.91	0.93	0.72
	UR2	0.89			
	UR3	0.87			
	UR4	0.86			
	UR5	0.82			
Sustainable City Development (SCD)	SCD1	0.79	0.89	0.91	0.69
	SCD2	0.83			
	SCD3	0.86			
	SCD4	0.82			
	SCD5	0.80			

In addition, discriminant validity was assessed using the Fornell–Larcker criterion, which requires the square root of each construct's AVE to exceed its correlations with other constructs. As shown in Table 4, the diagonal values (representing the square root of AVE) were higher than the corresponding inter-construct correlations, confirming adequate discriminant validity. These findings indicate that each construct captured a distinct concept and that overlap among the latent variables was limited. The CFA results therefore provide empirical support for the reliability, convergent validity, and discriminant validity of the measurement model, allowing the structural model and proposed hypotheses to be examined.

Table 4. Fornell–Larcker Criterion for Discriminant Validity

Construct	GI	GE	SCI	CP	UR	SCD
Green Infrastructure (GI)	**0.825**					
Governance Effectiveness (GE)	0.54	**0.860**				
Smart City Initiatives (SCI)	0.48	0.56	**0.806**			
Community Participation (CP)	0.51	0.58	0.49	**0.794**		
Urban Resilience (UR)	0.62	0.68	0.55	0.59	**0.849**	
Sustainable City Development (SCD)	0.56	0.61	0.52	0.54	0.71	**0.831**

Note: Diagonal values (bold) represent the square root of AVE; off-diagonal values represent inter-construct correlations.

Structural Model and Hypothesis Testing

Following the confirmation of the measurement model, the structural model was estimated using SEM with maximum likelihood estimation to examine the hypothesized relationships among the study constructs. The structural model evaluated the effects of Green Infrastructure (GI), Governance Effectiveness (GE), Smart City Initiatives (SCI), and Community Participation (CP) on Urban Resilience (UR), as well as the effect of Urban Resilience on Sustainable City Development (SCD). The overall goodness-of-fit indices indicated that the structural model provided an acceptable fit to the empirical data. Specifically, the model demonstrated a satisfactory fit with $\chi^2/df = 2.34$, Comparative Fit Index (CFI) = 0.96, Tucker–Lewis Index (TLI) = 0.95, Root Mean Square Error of Approximation (RMSEA) = 0.05, and Standardized Root Mean Square Residual (SRMR) = 0.04. These values satisfy commonly accepted threshold criteria for SEM model evaluation, confirming that the proposed structural framework adequately represented the observed relationships among the latent constructs. Figure 1 presents the standardized structural model with estimated path coefficients. The results demonstrate that all hypothesized relationships were positive and statistically significant ($p < 0.001$). Among the determinants of urban resilience, Governance Effectiveness exhibited the strongest positive effect ($\beta = 0.63$), followed by Green Infrastructure ($\beta = 0.58$), Community Participation ($\beta = 0.55$), and Smart City Initiatives ($\beta = 0.52$). These findings indicate that institutional, environmental, social, and technological factors all contribute significantly to strengthening urban resilience. Furthermore, Urban Resilience demonstrated a strong positive effect on Sustainable City Development (β = 0.71, $p < 0.001$), indicating that higher levels of urban resilience are associated with improved sustainability outcomes. The coefficient of determination (R^2) indicated that the four antecedent variables jointly explained 61.2% of the variance in Urban Resilience, demonstrating substantial explanatory power. In addition, Urban Resilience explained 50.4% of the variance in Sustainable City Development ($R^2 = 0.504$). The standardized path coefficients, critical ratios, significance levels, and hypothesis decisions are presented in Table 5. All five proposed hypotheses were supported.

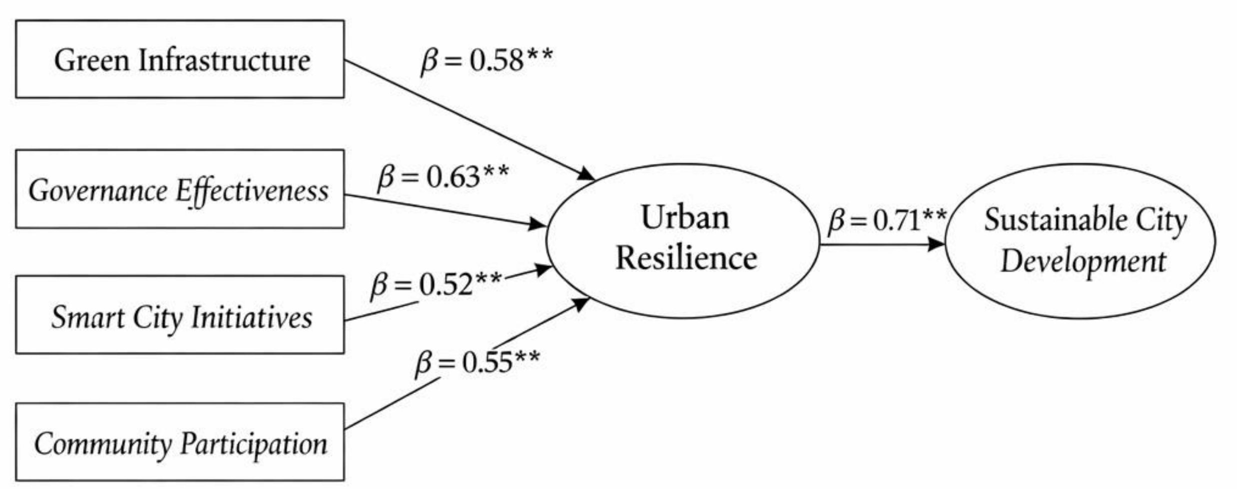

Figure 1. Standardized Structural Model

Table 5. Structural Path Coefficients and Hypothesis Testing Results

Hypothesis	Structural Path	Standardized β	Critical Ratio (C.R.)	p-value	Decision
H1	Green Infrastructure → Urban Resilience	0.58	9.42	<0.001	Supported
H2	Governance Effectiveness → Urban Resilience	0.63	11.25	<0.001	Supported
H3	Smart City Initiatives → Urban Resilience	0.52	8.67	<0.001	Supported
H4	Community Participation → Urban Resilience	0.55	9.15	<0.001	Supported
H5	Urban Resilience → Sustainable City Development	0.71	15.34	<0.001	Supported

Table 6. Explanatory Power of the Structural Model

Endogenous Construct	Predictors	R^2	Interpretation
Urban Resilience	GI, GE, SCI, CP	0.612	Substantial explanatory power
Sustainable City Development	Urban Resilience	0.504	Moderate-to-substantial explanatory power

Mediation Analysis

To examine whether Urban Resilience functions as an explanatory mechanism between the antecedent variables and Sustainable City Development, mediation analysis was conducted using the bootstrapping method with 5,000 resamples. The significance of indirect effects was evaluated using bias-corrected 95% confidence intervals. An indirect effect was considered statistically significant when the confidence interval did not include zero. The results demonstrated that Urban Resilience significantly mediated all proposed relationships between the antecedent variables and Sustainable City Development (Table 7). Specifically, Green Infrastructure had a significant indirect effect on Sustainable City Development through Urban Resilience (β = 0.412, $p < 0.001$). Similarly, Governance Effectiveness showed the strongest indirect effect through Urban Resilience (β = 0.447, $p < 0.001$), followed by Community Participation (β = 0.391, $p < 0.001$) and Smart City Initiatives (β = 0.369, p <

0.001). These findings confirm that Urban Resilience serves as an important mechanism through which environmental, institutional, technological, and social capacities contribute to sustainable city development.

Table 7. Mediation Effects of Urban Resilience

Hypothesis	Indirect Path	β	BootSE	95% Confidence Interval	p-value	Decision
H6	GI → UR → SCD	0.412	0.048	0.325–0.514	<0.001	Supported
H7	GE → UR → SCD	0.447	0.052	0.351–0.558	<0.001	Supported
H8	SCI → UR → SCD	0.369	0.045	0.281–0.462	<0.001	Supported
H9	CP → UR → SCD	0.391	0.047	0.300–0.489	<0.001	Supported

Discussion

The primary objective of this study was to investigate the determinants of urban resilience and examine how these determinants contribute to sustainable city development through an integrated SEM framework. The findings provide empirical evidence that green infrastructure, governance effectiveness, smart city initiatives, and community participation significantly enhance urban resilience. Furthermore, the mediation analysis extends these findings by demonstrating that urban resilience functions as a key mechanism through which these determinants are translated into sustainable city development outcomes. Thus, the study moves beyond identifying the factors associated with resilience and provides a deeper understanding of the process through which cities achieve sustainability.

The results confirm that urban resilience is a multidimensional capability shaped by the interaction of environmental, institutional, technological, and social systems. Previous approaches have often examined resilience determinants separately; however, the findings of this study demonstrate that resilient urban systems emerge from the combined contribution of multiple capacities. More importantly, the mediation results indicate that these capacities do not influence sustainable development only through direct improvements in urban conditions; rather, their sustainability benefits are largely realized by strengthening the adaptive capacity of cities (Jia & Turcu, 2025; Monadi, et al., 2025). This finding supports a systems perspective of urban resilience, where different urban components interact dynamically to enhance cities' ability to anticipate, absorb, adapt, and recover from disturbances. Among the examined determinants, governance effectiveness emerged as the strongest predictor of urban resilience ($\beta = 0.63$, $p < 0.001$). This finding highlights the central role of institutional capacity in shaping resilient urban systems. Effective governance enables coordinated planning, transparent decision-making, efficient resource allocation, stakeholder collaboration, and adaptive responses to emerging challenges. Urban resilience cannot be achieved solely through physical infrastructure or technological investments if institutional structures are unable to effectively manage and integrate these resources.

The mediation findings further strengthen the importance of governance effectiveness by showing that its contribution to sustainable city development occurs significantly through enhanced urban resilience. In other words, effective governance creates the institutional conditions necessary for resilience-building, and resilience subsequently facilitates sustainable urban outcomes. This finding emphasizes that governance should be considered not only as a direct contributor to resilience but also as a foundational mechanism supporting broader sustainability transitions. Green infrastructure was identified as the second strongest determinant of urban resilience ($\beta = 0.58$, $p < 0.001$). This result confirms the importance of nature-based solutions in addressing contemporary urban challenges. Green spaces, urban forests, wetlands, ecological corridors, and sustainable drainage systems provide essential ecosystem services that improve environmental quality, reduce climate-related risks, and enhance urban adaptability. By mitigating heat effects, managing stormwater, improving biodiversity, and supporting public well-being, green infrastructure contributes significantly to the resilience of urban systems (Frantzeskaki, et al., 2024; Monadi, et al., 2025).

The mediation analysis demonstrates that green infrastructure contributes to sustainable city development partly because it strengthens urban resilience. This finding suggests that ecological interventions should not be viewed merely as environmental improvements but as strategic resilience investments. Cities that integrate green infrastructure into their planning frameworks are better positioned to maintain environmental stability and achieve long-term sustainability objectives under conditions of uncertainty. Community participation also demonstrated a significant positive relationship with urban resilience ($\beta = 0.55$, $p < 0.001$). This finding reinforces the argument that resilient cities are fundamentally people-centered systems. Residents possess valuable local knowledge, social networks, and collective capabilities that enhance preparedness, adaptation, and recovery during periods of disruption. Participatory planning processes increase public trust, improve policy acceptance, and encourage shared responsibility for urban development (Ezzati, et al., 2024; Lv & Sarker, 2024).

The mediation results provide additional evidence that community participation contributes to sustainability by strengthening the social dimensions of resilience. Through greater citizen involvement, cities can develop stronger social cohesion, improve collective problem-solving capacity, and enhance their ability to respond effectively to environmental and social challenges. Smart city initiatives also significantly influenced urban resilience ($\beta = 0.52$, $p < 0.001$). Digital technologies, including real-time monitoring systems, intelligent infrastructure, data-driven governance platforms, and advanced information systems, provide cities with improved capabilities for risk assessment, service optimization, and emergency management. However, technological advancement alone does not automatically produce resilient outcomes. The indirect effect analysis confirms that smart city initiatives support sustainable development primarily when they enhance urban resilience capacities. Therefore, smart city strategies should be implemented within broader resilience frameworks that emphasize institutional readiness, digital inclusion, public trust, and equitable access to technology (Monadi & Hoseinzadeh dalir, 2022; Vandrevala, et al., 2024).

A major contribution of this study is the identification of urban resilience as a mediating mechanism between urban capacities and sustainable city development. The structural model demonstrated a strong direct relationship between urban resilience and sustainable city development ($\beta = 0.71$, $p < 0.001$), while the mediation analysis confirmed significant indirect effects of green infrastructure, governance effectiveness, smart city initiatives, and community participation through urban resilience. These findings change the interpretation of urban resilience from being merely an outcome of successful urban strategies to being an active transformation mechanism through which urban resources and capacities generate sustainability benefits (Wang, et al., 2024). In other words, environmental investments, institutional improvements, technological innovations, and social engagement contribute to sustainable development because they enhance the ability of cities to adapt and maintain essential functions under changing conditions. The mediating role of urban resilience provides empirical support for the integration of resilience and sustainability perspectives. Sustainable cities require more than efficient resource use or environmental protection; they must also possess the capacity to respond to unexpected disruptions and continuously adapt to new challenges (Xu, et al., 2021). Therefore, resilience represents the operational pathway through which sustainability objectives can be maintained over time.

This study contributes to urban sustainability and resilience literature in several ways. First, it develops an integrated framework combining environmental, institutional, technological, and social determinants of urban resilience. Rather than examining isolated factors, the study demonstrates that resilience emerges from the interaction of multiple urban systems. Second, the study advances theoretical understanding by empirically validating the mediating role of urban resilience. Previous studies have frequently examined whether certain factors influence resilience or sustainability independently. This research demonstrates how resilience connects these two domains by explaining the mechanism through which urban capacities contribute to sustainable development. Third, the findings reinforce adaptive governance theory by demonstrating the importance of institutional effectiveness in creating resilient urban systems. Governance effectiveness was identified as the strongest determinant, suggesting that institutional capacity provides the foundation upon which other resilience dimensions operate. Finally, the study demonstrates the usefulness of SEM for analyzing complex urban phenomena involving multiple latent constructs and indirect relationships. The validated model provides a comprehensive framework for future research examining resilience-based pathways toward sustainable urban transformation.

The findings provide important implications for policymakers and urban planners. Since governance effectiveness represents the strongest determinant of resilience, municipal authorities should prioritize institutional strengthening, transparent decision-making, strategic coordination, and adaptive planning approaches. The mediation findings indicate that policymakers should not only invest in individual resilience determinants but also focus on how these investments strengthen overall urban resilience capacity. For example, green infrastructure projects, smart technologies, and participatory planning initiatives should be evaluated according to their contribution to adaptive capacity and long-term sustainability outcomes. Urban governments should integrate ecosystem-based approaches into development plans, expand opportunities for citizen participation, and implement smart technologies within inclusive governance frameworks. Such integrated strategies can enhance resilience while simultaneously supporting sustainable development objectives.

Despite its contributions, this study has several limitations. First, the cross-sectional design limits the ability to establish long-term causal relationships. Future longitudinal studies could examine how resilience capacities evolve over time and how they influence sustainability outcomes under changing conditions. Second, the study relied primarily on residents' perceptions of urban resilience and sustainable development. Future research could combine survey-based assessments with objective indicators, including geographic information systems, environmental monitoring data, infrastructure performance measures, and administrative records. Third, although this study identified urban resilience as an important mediator, future research could examine additional mediating and moderating mechanisms. Variables such as institutional trust, social capital, climate adaptation capacity, environmental awareness, and digital inclusion may provide further insights into the complex pathways connecting urban strategies and sustainability outcomes.

In conclusion, this study demonstrates that sustainable city development depends not only on improving environmental, institutional, technological, and social capacities but also on strengthening urban resilience as a central mechanism connecting these capacities to sustainability outcomes. The most important contribution of this research is the empirical confirmation that urban resilience functions as a mediating pathway through which governance effectiveness, green infrastructure, smart city initiatives, and community participation generate sustainable urban development benefits. The findings show that resilient cities are created through coordinated strategies that combine effective institutions, ecological planning, technological innovation, and citizen engagement. As cities face increasing pressures from climate change, rapid urbanization, and socioeconomic uncertainty, resilience-oriented planning will become increasingly essential. Therefore, urban resilience should not be considered only as a response capacity after crises occur but as a proactive foundation for achieving inclusive, adaptive, and sustainable cities.

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