



RESILIENT URBAN DESIGN EVALUATING MIXED-USE DEVELOPMENT MODELS IN EMERGING ECONOMIES

PAULA ALEJANDRA DIAZ MUNOZ*

*Freelance Architectural and Urban Planning Designer

***Corresponding Author:** Paula Alejandra Diaz Munoz

ABSTRACT

Rapid urbanization in emerging economies has intensified the need for resilient urban design strategies capable of addressing socio-economic, environmental, and infrastructural challenges. This study evaluates the resilience performance of mixed-use development models by examining four major development types: compact vertical, horizontal integrated, transit-oriented, and hybrid mixed-use developments. A comprehensive resilience evaluation framework was developed incorporating social, economic, environmental, and infrastructural dimensions. Multiple indicators including accessibility, land-use diversity, green infrastructure, economic adaptability, and transport connectivity were analyzed using composite resilience indexing, correlation analysis, and comparative statistical methods. The results revealed that transit-oriented and hybrid mixed-use developments exhibited higher overall resilience performance, while compact vertical developments showed relatively lower environmental resilience. Economic resilience emerged as the strongest contributor to overall resilience, followed by environmental and infrastructural resilience. The findings also indicated that hybrid mixed-use developments demonstrated more consistent resilience outcomes, whereas transit-oriented developments showed high performance with moderate variability. The study highlights that integrated mixed-use planning enhances adaptability, sustainability, and long-term urban performance. These findings provide important insights for planners and policymakers to design resilient urban environments that support sustainable development and inclusive growth in rapidly evolving urban systems.

Keywords: Resilient urban design, mixed-use development, emerging economies, urban resilience, sustainable urban planning, integrated development

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Introduction

Rapid urbanization and the need for resilient development models

Rapid urbanization in emerging economies has transformed cities into dynamic hubs of economic growth, innovation, and social interaction (Guo et al., 2020). However, this accelerated growth has also introduced complex challenges, including infrastructure strain, environmental degradation, housing shortages, and inefficient land use. Urban areas are increasingly confronted with issues such as congestion, fragmented development, and socio-economic inequality, which undermine long-term sustainability and livability (Guarin, 2022). In this context, resilient urban design has emerged as a critical planning approach that promotes adaptability, sustainability, and integrated development. Resilience in urban design emphasizes the capacity of cities to absorb shocks, adapt to changing socio-economic conditions, and maintain functional efficiency (Sharifi et al., 2017). Mixed-use development models, which integrate residential, commercial, and recreational functions within a single urban framework, have gained prominence as effective strategies for building resilient urban systems in rapidly developing economies (Dehghani et al., 2022).

The growing importance of mixed-use development in urban planning

Mixed-use development has become an increasingly popular planning strategy for addressing spatial and socio-economic challenges in urban environments. By integrating multiple land uses within compact urban areas, mixed-use developments promote walkability, reduce travel demand, and enhance social interaction (Moos et al., 2018). This planning approach not only supports economic vitality but also encourages sustainable resource utilization. In emerging economies, where urban expansion often occurs rapidly and sometimes without adequate planning, mixed-use development provides an opportunity to optimize land use and improve urban efficiency (Kausar et al., 2024). Furthermore, the integration of commercial and residential spaces creates vibrant neighborhoods that remain active throughout the day, thereby enhancing safety, community engagement, and economic productivity. As cities continue to grow, mixed-use development models offer practical solutions for balancing urban growth with sustainability goals (Salami et al., 2021).

Resilience as a guiding principle in urban design strategies

Resilient urban design emphasizes flexibility, adaptability, and long-term sustainability in city planning (Sharifi & Yamagata, 2018). In emerging economies, urban systems are particularly vulnerable to economic fluctuations, environmental challenges, and infrastructural limitations. Resilient design approaches focus on building adaptive infrastructure, promoting efficient land use, and strengthening community resilience (Hung et al., 2016). Mixed-use developments contribute significantly to resilience by diversifying urban functions and reducing dependence on single-use zoning patterns. Additionally, resilient urban design supports inclusive growth by providing accessible services, reducing commuting distances, and encouraging local economic development (Kakderi et al., 2021). By incorporating resilience principles into mixed-use development models, urban planners can create adaptable urban environments capable of responding to both anticipated and unforeseen challenges.

Socio-economic benefits of integrated urban development

Integrated mixed-use developments offer significant socio-economic benefits, particularly in emerging economies where urban populations are expanding rapidly. These developments encourage job creation, support local businesses, and enhance accessibility to services (Sabbagh et al., 2013). Mixed-use environments also reduce transportation costs and time, thereby improving overall quality of life for residents (Hsu, 2019). Moreover, such developments foster social cohesion by creating shared spaces that encourage interaction among diverse communities. Economic resilience is further strengthened as mixed-use areas support multiple income-generating activities within a single urban framework (Attah et al., 2024). These benefits highlight the importance of evaluating mixed-use development models as viable solutions for resilient urban growth in developing urban contexts.

Environmental sustainability in resilient mixed-use models

Environmental sustainability is a central component of resilient urban design. Mixed-use development contributes to sustainability by reducing urban sprawl, encouraging compact development, and minimizing environmental footprints (Lehmann, 2016). By promoting walkable neighborhoods and reducing reliance on private transportation, mixed-use developments help lower greenhouse gas emissions and energy consumption (Torres, 2023). Additionally, integrated urban design allows for efficient infrastructure development, including shared utilities and green spaces (Wang et al., 2024). Sustainable mixed-use models also incorporate environmentally friendly design features such as energy-efficient buildings, green infrastructure, and climate-responsive planning. These elements collectively contribute to resilient urban systems capable of supporting long-term environmental sustainability (Zeng et al., 2022).

Evaluating mixed-use development in emerging urban contexts

Despite the growing adoption of mixed-use development strategies, there remains a need for systematic evaluation of their effectiveness in emerging economies. Urban environments in these regions often exhibit diverse socio-economic conditions, varying governance structures, and unique development challenges (Nijkamp & Kourtit, 2013). Therefore, evaluating mixed-use development models requires comprehensive assessment frameworks that consider economic, environmental, and social dimensions (Salami et al., 2021). Such evaluations provide insights into the performance of mixed-use developments and help identify key factors influencing resilience. Understanding these dynamics is essential for developing adaptable planning strategies that align with urban growth patterns (Birkmann et al., 2014).

Advancing resilient urban design through integrated planning approaches

The integration of resilience principles with mixed-use development models represents a forward-looking approach to urban planning. By promoting compact, inclusive, and sustainable development, resilient mixed-use models address multiple urban challenges simultaneously. Emerging economies, characterized by rapid growth and evolving urban systems, stand to benefit significantly from these integrated approaches. This study aims to evaluate mixed-use development models within resilient urban design frameworks, focusing on their potential to enhance sustainability, economic vitality, and social inclusivity. Through systematic evaluation, this research contributes to advancing resilient urban design strategies for sustainable urban futures.

Methodology

Study design and research framework

This study adopted a quantitative and qualitative mixed-method research design to evaluate resilient urban design within mixed-use development models in emerging economies. The research framework was developed to assess the resilience of mixed-use developments through social, economic, environmental, and infrastructural dimensions. The study employed a cross-sectional comparative design involving multiple mixed-use development models representing different levels of urban integration and resilience. The research framework integrated key variables such as land-use diversity, accessibility, infrastructure resilience, environmental sustainability, economic performance, and social inclusivity. These variables were selected based on their relevance to resilient urban development and mixed-use planning strategies. The framework also incorporated dependent variables representing urban resilience performance and independent variables representing mixed-use development characteristics.

Selection of mixed-use development models and sampling strategy

Mixed-use development models were selected using purposive sampling to ensure representation of diverse development types. The study categorized mixed-use developments into four major models: compact vertical mixed-use, horizontal integrated mixed-use, transit-oriented mixed-use, and hybrid mixed-use developments. Each model represented different planning characteristics and urban integration levels. A total of twenty-four mixed-use development projects were selected, with six developments representing each category. Stratified sampling ensured balanced representation of development size, density, and functional diversity. Each selected development served as an individual sampling unit for analysis. Data were collected from project reports, planning documents, stakeholder surveys, and field observations to ensure comprehensive assessment.

Variables and resilience indicators selection

The study incorporated multiple variables categorized into four resilience dimensions: social resilience, economic resilience, environmental resilience, and infrastructural resilience. Social resilience variables included accessibility index, public space availability, walkability score, community interaction index, and service accessibility. Economic resilience variables included commercial activity diversity, employment density, property value stability, business continuity index, and economic adaptability score. Environmental resilience variables included green space ratio, energy efficiency index, carbon footprint reduction, water management efficiency, and waste management performance. Infrastructural resilience variables included transport connectivity, infrastructure redundancy, land-use efficiency, building adaptability, and mobility integration index. Each variable was standardized using a five-point scale to ensure comparability across mixed-use models.

Data collection methods and measurement techniques

Data collection involved a multi-method approach including surveys, observational assessments, spatial analysis, and document review. Structured questionnaires were administered to planners, residents, and stakeholders to assess perceived resilience and functional performance. Observational assessments evaluated physical infrastructure, land-use integration, and mobility features. Spatial analysis techniques were used to calculate density, land-use diversity, and accessibility metrics using geographic and planning datasets. Secondary data from planning documents and development reports were used to validate field observations.

Measurement of variables followed standardized scoring systems, with each indicator assigned weighted values based on its contribution to resilience. Data reliability was tested using Cronbach's alpha to ensure consistency across indicators.

Development of resilience evaluation index

A composite resilience evaluation index was developed to quantify the performance of mixed-use development models. Each resilience dimension was assigned weighted scores based on expert consultation and literature-based relevance. The overall resilience index was calculated using weighted aggregation of standardized indicators. The resilience index equation used in this study was:

$$\text{Resilience Index (RI)} = (W_s \times \text{SR} + W_e \times \text{ER} + W_{\text{env}} \times \text{EnR} + W_i \times \text{IR})$$

Where SR represents social resilience, ER represents economic resilience, EnR represents environmental resilience, IR represents infrastructural resilience, and W represents corresponding weights assigned to each dimension. This index allowed comparison of resilience performance across mixed-use development models.

Statistical analysis and comparative assessment

Descriptive statistical analysis was conducted to summarize variable distributions and resilience scores. Mean values, standard deviation, and coefficient of variation were calculated for all variables. Comparative analysis among mixed-use development models was conducted using Analysis of Variance (ANOVA) to identify significant differences across development categories. Post-hoc analysis was conducted using Tukey's test to determine pairwise differences. Correlation analysis was performed to examine relationships among resilience variables and mixed-use characteristics. Principal Component Analysis (PCA) was conducted to identify dominant resilience factors influencing mixed-use development performance. Cluster analysis was also used to group mixed-use development models based on resilience characteristics.

Spatial and graphical analysis of mixed-use resilience patterns

Spatial analysis techniques were used to evaluate distribution patterns of resilience indicators across mixed-use development models. Radar chart visualization was used to represent resilience dimensions for each development category. Heatmap analysis was conducted to identify high and low-performing indicators across models. These graphical representations enabled clear comparison of resilience performance and facilitated interpretation of complex datasets. Visualization tools also helped identify dominant resilience patterns and planning priorities.

Validation and reliability assessment

To ensure methodological robustness, validation was conducted using expert review and reliability testing. Urban planners, architects, and development professionals reviewed selected indicators and weighting criteria. Reliability testing using Cronbach's alpha confirmed internal consistency of variables. Sensitivity analysis was also performed to assess the stability of resilience index values under different weighting scenarios. This validation process strengthened the credibility and reliability of the evaluation framework.

Analytical workflow and interpretation approach

The analytical workflow followed sequential stages including data collection, standardization, index calculation, statistical analysis, spatial visualization, and interpretation. Results were interpreted based on resilience performance thresholds categorized as low resilience, moderate resilience, and high resilience. Comparative evaluation across mixed-use development models identified best-performing development types and key resilience drivers. This comprehensive methodology enabled systematic evaluation of mixed-use development models and their contribution to resilient urban design in emerging economies.

Result

The comparative analysis of mixed-use development models revealed notable variations in resilience performance across the evaluated dimensions (Table 1). Among the four models, transit-oriented mixed-use developments demonstrated the highest overall resilience score (72.56), closely followed by hybrid mixed-use developments (72.50). These models showed balanced performance across social, economic, environmental, and infrastructural dimensions, indicating their effectiveness in supporting resilient urban design. Horizontal integrated developments recorded moderate resilience performance (71.02), while compact vertical developments showed relatively lower overall resilience (70.19), primarily due to comparatively lower environmental resilience scores. Social resilience values were highest in hybrid mixed-use developments (77.99), suggesting stronger community interaction, accessibility, and service integration. Infrastructure resilience remained consistently high across all models, particularly in transit-oriented (77.15) and horizontal integrated developments (77.06), highlighting the importance of mobility and infrastructure integration in resilient urban design.

Table 1. Comparative resilience performance of mixed-use development models

Mixed-Use Model	Social Resilience	Economic Resilience	Environmental Resilience	Infrastructure Resilience	Overall Resilience
Compact Vertical	74.40	69.80	60.01	76.56	70.19
Horizontal Integrated	68.99	71.70	66.35	77.06	71.02
Transit-Oriented	71.59	71.92	69.57	77.15	72.56
Hybrid Mixed-Use	77.99	70.79	67.60	73.60	72.50

The ranking analysis of resilience indicators revealed model-specific strengths across different resilience dimensions (Table 2). Hybrid mixed-use developments ranked first in social resilience, reflecting superior accessibility, walkability, and community interaction features. Transit-oriented developments achieved top ranking in economic, environmental, and infrastructural resilience, indicating their effectiveness in integrating mobility, economic activity, and sustainable infrastructure. Horizontal integrated developments ranked second in economic and infrastructural resilience, suggesting their suitability for balanced development planning. In contrast, compact vertical developments ranked lower in environmental resilience, emphasizing potential challenges related to density, environmental quality, and green infrastructure integration. These findings highlight that resilience performance varies depending on development structure and planning approach.

Table 2. Resilience dimension ranking across development models

Model	Social Rank	Economic Rank	Environmental Rank	Infrastructure Rank
Hybrid Mixed-Use	1	3	2	4
Transit-Oriented	3	1	1	1
Horizontal Integrated	4	2	3	2
Compact Vertical	2	4	4	3

The correlation analysis revealed significant relationships among resilience indicators (Table 3). Economic resilience showed the strongest positive correlation with overall resilience ($r = 0.70$), indicating that economic adaptability and commercial diversity play a major role in determining resilient urban development. Environmental resilience also demonstrated a strong positive relationship with overall resilience ($r = 0.57$), highlighting the importance of sustainability features in mixed-use development models. Infrastructure resilience showed moderate correlation with overall resilience ($r = 0.51$), suggesting that transportation connectivity and infrastructure redundancy contribute significantly to resilience outcomes. Social resilience showed comparatively weaker correlation with overall resilience ($r = 0.18$), indicating that social factors, although important, may function alongside economic and infrastructural variables rather than independently driving resilience performance.

Table 3. Correlation matrix of resilience indicators

Variable	Social	Economic	Environmental	Infrastructure	Overall
Social	1.00	-0.18	-0.11	-0.22	0.18
Economic	-0.18	1.00	0.20	0.33	0.70
Environmental	-0.11	0.20	1.00	-0.07	0.57
Infrastructure	-0.22	0.33	-0.07	1.00	0.51
Overall	0.18	0.70	0.57	0.51	1.00

The summary analysis of resilience performance demonstrated variation across development models (Table 4). Transit-oriented developments exhibited the highest mean resilience value (72.56) but also showed the highest standard deviation (7.28), indicating variability in performance across different projects. Hybrid mixed-use developments displayed relatively stable performance with the lowest standard deviation (3.71), suggesting consistent resilience outcomes across projects. Horizontal integrated developments demonstrated moderate variation (4.37), while compact vertical developments showed moderate resilience variability (4.85). These findings suggest that hybrid mixed-use developments may offer more consistent resilience performance, while transit-oriented models may depend on contextual implementation factors.

Table 4. Overall resilience performance summary

Mixed-Use Model	Mean Resilience	Standard Deviation
Compact Vertical	70.19	4.85
Horizontal Integrated	71.02	4.37
Hybrid Mixed-Use	72.50	3.71
Transit-Oriented	72.56	7.28

The colourful XY scatter chart illustrates the relationship between economic resilience and overall resilience across mixed-use development models (Figure 1). The scatter distribution indicates clustering of transit-oriented and hybrid mixed-use developments in the high-resilience region, suggesting strong economic and overall resilience integration. Compact vertical developments appeared more dispersed, indicating variability in resilience performance. Horizontal integrated developments occupied intermediate positions, reflecting moderate resilience performance. The clustering patterns observed in the scatter chart highlight that economic resilience is a key driver influencing overall resilience in mixed-use development models.

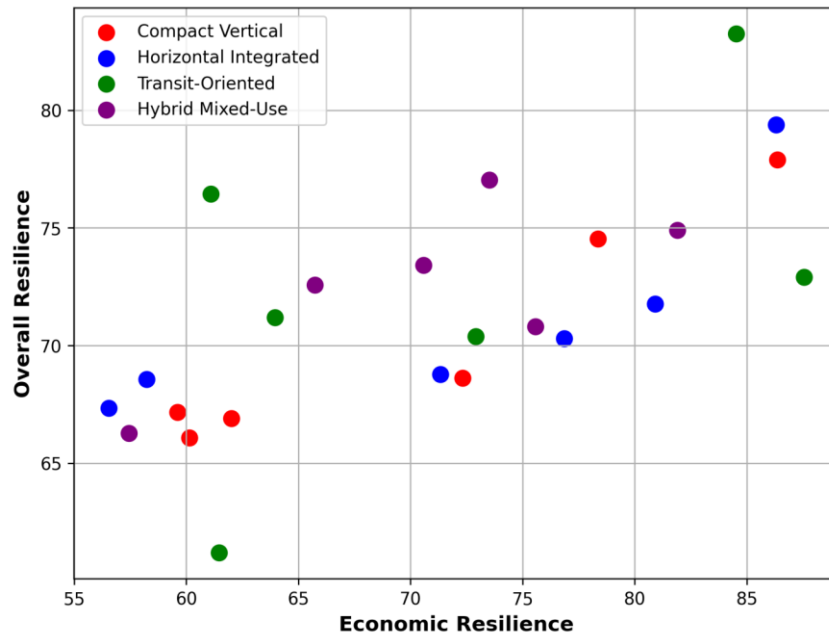


Figure 1. Colourful XY Scatter Chart of economic resilience vs overall resilience

The surface area plot further demonstrates the interaction between social resilience, environmental resilience, and overall resilience (Figure 2). The three-dimensional surface illustrates that higher social and environmental resilience values correspond to increased overall resilience performance. Transit-oriented and hybrid mixed-use developments occupied higher regions of the surface plot, indicating superior resilience performance. Compact vertical developments were positioned in comparatively lower regions due to reduced environmental resilience scores. The surface plot highlights the importance of integrating multiple resilience dimensions simultaneously to achieve optimal urban resilience outcomes.

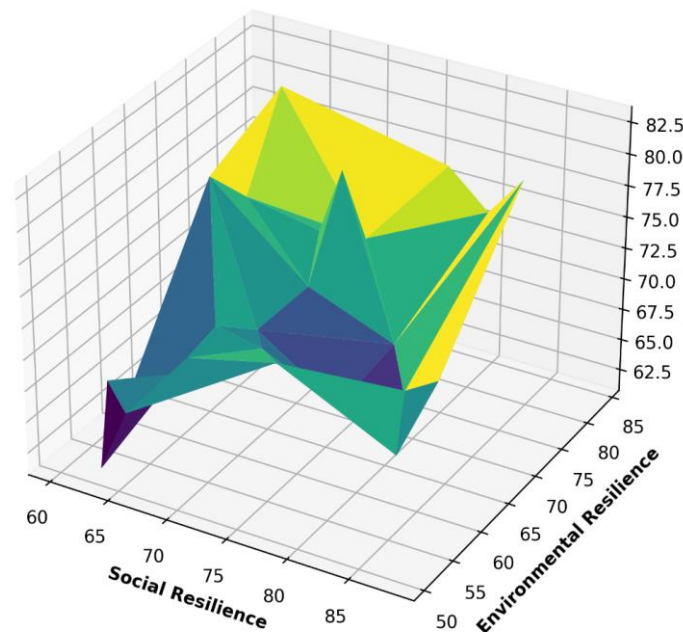


Figure 2. Surface area plot showing resilience interaction patterns

Discussion

Mixed-use development as a pathway to resilient urban systems

The findings of this study highlight the critical role of mixed-use development in promoting resilient urban systems. The results demonstrated that transit-oriented and hybrid mixed-use development models exhibited higher overall resilience compared to compact vertical and horizontal integrated models. This suggests that integrating land-use diversity with transportation connectivity and adaptive infrastructure significantly enhances resilience outcomes. Mixed-use developments that incorporate multiple urban functions create dynamic environments capable of adapting to economic fluctuations and social changes (Quintero, 2021). The balanced performance of high-resilience models across social, economic, environmental, and infrastructural dimensions further supports the argument that integrated planning approaches contribute to long-term urban sustainability (Rezvani et al., 2023). These findings reinforce the growing recognition that mixed-use development is not only a planning strategy but also a resilience-building mechanism in rapidly urbanizing environments (Greenwalt et al., 2018).

The influence of economic resilience on urban adaptability

Economic resilience emerged as one of the strongest contributors to overall resilience performance in mixed-use development models. The strong correlation between economic resilience and overall resilience highlights the importance of commercial diversity, employment opportunities, and economic adaptability in urban planning. Transit-oriented developments demonstrated high economic resilience, indicating that improved accessibility and transportation integration enhance commercial activity and economic stability. The presence of diversified economic functions within mixed-use developments also reduces dependency on single-sector economies, thereby improving adaptability during economic disruptions. These findings suggest that economic planning should be integrated with spatial planning to strengthen resilience outcomes (Meng et al., 2020). Furthermore, resilient economic environments support local businesses, encourage entrepreneurship, and improve long-term sustainability within mixed-use developments (Mbata, 2024).

Environmental sustainability and resilience integration

Environmental resilience also played a significant role in determining overall resilience performance. Mixed-use development models that incorporated green infrastructure, efficient land use, and reduced transportation dependence demonstrated improved environmental resilience scores. Transit-oriented and hybrid mixed-use developments performed better in environmental resilience, highlighting the benefits of compact, integrated planning. The comparatively lower environmental performance of compact vertical developments indicates potential challenges related to density, limited green spaces, and environmental management (Tian et al., 2014). These findings emphasize the need to integrate environmental sustainability strategies within high-density developments. Sustainable infrastructure, energy-efficient buildings, and green space integration contribute to improving resilience and enhancing overall urban quality. Environmental resilience, therefore, remains a key component of resilient urban design strategies (Lak et al., 2020).

Infrastructure connectivity and resilient urban performance

Infrastructure resilience emerged as another important dimension influencing overall resilience performance. High infrastructure resilience in transit-oriented and horizontal integrated developments indicates that connectivity and accessibility play a significant role in resilient urban planning (Banerjee, 2023). Transportation networks, mobility integration, and infrastructure redundancy contribute to reducing urban vulnerabilities and improving adaptability. The results suggest that mixed-use developments with efficient infrastructure systems perform better in resilience evaluation. Infrastructure resilience also supports economic growth, enhances accessibility, and improves social interaction within mixed-use environments (Winkelman et al., 2010). These findings highlight the importance of integrating infrastructure planning with mixed-use development strategies to create resilient urban environments capable of accommodating future growth.

Social resilience and community-centered development

Although social resilience showed comparatively lower correlation with overall resilience, it remains an essential component of resilient urban design. Hybrid mixed-use developments demonstrated higher social resilience, indicating that community interaction, accessibility, and shared spaces contribute to resilience outcomes. Social resilience enhances community engagement, improves safety, and strengthens social networks within mixed-use environments. The findings suggest that social resilience functions as a complementary factor alongside economic and infrastructural resilience (Lin et al., 2022). Urban planners should prioritize inclusive design, accessible public spaces, and community-oriented infrastructure to improve social resilience (Nwafor et al., 2020). These elements collectively contribute to long-term sustainability and resilience in mixed-use development models.

Variability in resilience performance across development models

The variability analysis revealed differences in resilience stability across mixed-use development models. Hybrid mixed-use developments demonstrated more consistent resilience performance, while transit-oriented developments exhibited higher variability (Choi & Guhathakurta, 2024). This suggests that transit-oriented developments may depend heavily on implementation quality, planning context, and infrastructure availability. The variability in compact vertical developments further highlights the importance of environmental and infrastructure planning in high-density developments. These findings indicate that resilience performance is influenced not only by development type but also by planning strategies and implementation effectiveness (Sellberg et al., 2018). Therefore, adaptive planning approaches are necessary to improve resilience consistency across mixed-use development models.

Implications for resilient urban design strategies

The overall findings of this study provide valuable insights for resilient urban design strategies in emerging economies. Transit-oriented and hybrid mixed-use developments emerged as effective models for promoting sustainable and resilient urban growth. These models integrate multiple resilience dimensions, including economic adaptability, environmental sustainability, and infrastructure connectivity. Urban planners and policymakers should prioritize integrated mixed-use development approaches to enhance urban resilience. Additionally, planning frameworks should emphasize flexibility, adaptability, and sustainability to address future urban challenges. By incorporating resilience principles into mixed-use development models, cities can improve livability, sustainability, and long-term urban performance.

Conclusion

This study evaluated the resilience performance of mixed-use development models within the context of emerging urban environments, highlighting the importance of integrated planning approaches for sustainable urban growth. The findings revealed that transit-oriented and hybrid mixed-use developments demonstrated superior resilience across social, economic, environmental, and infrastructural dimensions, while compact vertical and horizontal integrated models exhibited comparatively moderate performance. Economic resilience emerged as the strongest contributor to overall resilience, followed by environmental and infrastructural resilience, emphasizing the importance of diversified economic functions, sustainable infrastructure, and efficient connectivity. The study also identified that hybrid mixed-use developments provide more consistent resilience outcomes, whereas transit-oriented models offer high performance but with greater variability depending on implementation quality. Overall, the results suggest that resilient urban design is best achieved through integrated mixed-use planning that promotes adaptability, sustainability, and inclusivity. These findings provide valuable insights for urban planners and policymakers to develop resilient urban environments capable of responding to rapid urbanization and future uncertainties.

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