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University Science and Technology Innovation Parks as Catalysts for Smart and Sustainable Cities: A Systematic Review of Global Models

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A b s t r a c t

University Science and Technology Innovation Parks (USTIPs) play a crucial role in shaping knowledge-based economies and advancing the transformation towards smart and sustainable cities. This paper systematically reviews global studies to examine how USTIPs function as important hubs for urban innovation, sustainable development, and design transformation. The review synthesizes key findings from global models, focusing on architectural strategies, spatial organization, digital infrastructures, sustainability practices, and policy frameworks that influence the performance of USTIPs. The findings indicate that well-designed USTIPs help facilitate the development of smart city by promoting technology transfer, enhancing university–industry–government collaboration, and utilizing IoT and AI technologies to achieve a sustainable urban environment. In urban design, USTIPs help promote compact city growth, urban walkability, climate-resilient planning, and low-carbon city development. The study concludes by highlighting key design and policy implications aimed at strengthening USTIPs as strategic catalysts for future urban innovation and sustainable city development.

K e y w o r d s : Innovation Ecosystems; Smart Cities; Sustainable Urban Development; University Science and Technology Parks; Urban Design.

1. Introduction

University Science and Technology Innovation Parks (USTIPs) have recently emerged as leading hubs in the global knowledge economy, which links the universities, industries, and governments in driving 21st century innovation, entrepreneurship, and technological advancement (Wu et al., 2025a). USTIPs are anchored in the triple helix model that provides a structured framework that facilitate knowledge transfer, commercialization of research outputs and formation of start-up enterprises (Đonlagić Alibegović et al., 2023; Ghazinoory et al., 2024). As urban centres and cities in developed countries increasingly evolve into a knowledge based and innovation driven centres, USTIPs have become strategic tools for facilitating economic transformation and improving long term competitiveness through start-up formation and high-technology industries (Ávila et al., 2025; Valdaliso & Andrés, 2025).

Over the past few decades, USTIPs transformation has rapidly extended beyond their role as conventional research and business clusters to incorporate a broader perspective of urban development to promote sustainability, and supports smart city initiatives (Anton-Tejon et al., 2024; Sandoval Hamón et al., 2024). USTIPs have increasingly recognized as catalysts that influence land-use dynamics, urban growth patterns, and infrastructure development while simultaneously facilitating sustainable development goals (SDGs) and smart city agendas (Abdullah Kaiser & Deb, 2025; Min & Liu, 2024; Wu et al., 2025b). This integration enables USTIPs to function not only as technological innovation hubs but also dynamic urban districts that influence land-use dynamics, transportation systems, and socio-economic interactions within such cities. Hence, leading to a more compacted, mixed-use, and innovation-driven urban environments (Yang et al., 2025).

USTIPs contribute significantly towards the development of a smart and sustainable city through the adoption of cutting-edge digital technologies, smart mobility systems, and environmentally responsive design strategies (Ávila et al., 2025; Jiao et al., 2025). Many present-day USTIPs incorporate energy-efficient buildings, renewable energy technologies, smart mobility solutions, intelligent waste management systems, and green open spaces, aligning their development trajectories with broader sustainability agendas such as climate resilience, resource efficiency, and low-carbon development (Anton-Tejon, 2024; Hui et al., Amen et al., 2023; 2023; Meyer & Shah, 2025; Aziz Amen & Ali, 2025). Also, USTIPs exert significant impact on urban morphology, architectural typologies, and public space integration through the adoption of mixed-use development with walkable spaces, compact urban form, and spatial design strategies that encourage social interaction, creativity, and collaboration for knowledge exchange (Coletto et al., 2024; Jiang et al., 2025; Makhdoom et al., 2022).

Despite their growing 21st century prominence, the performance and impacts of USTIPs vary considerably across regions due to differences in governance structures, planning frameworks, funding mechanisms, and socio-economic contexts. While existing studies have extensively examined the economic and technological outcomes of USTIPs, there remains a notable gap in systematically synthesizing how their spatial configuration, governance structures, and urban design frameworks jointly influence smart and sustainable city development.

Therefore, the present study conducts a systematic review of global USTIP models to synthesize existing evidence on their spatial, governance, and technological dimensions, examine their urban morphological patterns, and analyze their role in shaping smart and sustainable city development. By integrating innovation theory with urban design and planning perspectives, the study provides a conceptual framework that advances understanding of USTIPs as integrated urban innovation ecosystems.

2. Conceptual and Theoretical Framework

This study's conceptual and theoretical frameworks are grounded in an understanding of University Science and Technology Innovation Parks (USTIPs) as spatially integrated innovation hubs that exhibit a complex interrelationship between knowledge creation, urban expansion, and the global sustainability agenda (Anton-Tejon et al., 2024; Coletto et al., 2024; Valdaliso & Andrés, 2025). Earlier studies show that, rather than operating solely as economic or technological entities, most emerging twenty-first-century USTIPs are conceptualized as unified urban hubs with spatial patterns, governance structures, and technological infrastructure that jointly influence smart and sustainable city outcomes (Appio et al., 2019; Pan et al., 2024; Zhou et al., 2025). Therefore, these findings enable the bridging of innovation theory with architectural and urban design considerations.

2.1 Triple Helix Model and Spatialization of Innovation

The framework relies on the Triple Helix Model of innovation, which highlights the dynamic interaction and synergy between universities, industry, and government in improving knowledge-based development (Cai & Etzkowitz, 2021; Etzkowitz & Leydesdorff, 2025). Within the context of USTIPs, these interactions emerge through the planning and design of research facilities, innovation hubs, business incubators, and other collaborative public spaces (Nauwelaers et al., 2019; Schnell & Berger, 2025). However, the efficacy of such interactions is greatly influenced by the urban design, and extent of physical and functional integration with the surrounding city fabric. These observations highlight the need to extend the Triple Helix Model beyond institutional collaborations to include spatial and urban design considerations.

2.2 Smart City Theory and Digital-Technological Integration

The principles of smart city theory are further incorporated to highlight the role of digital and artificial intelligence technologies, as well as data-driven governance, in improving productivity and quality of life in urban environments (Kumar et al., 2024a; Zhang et al., 2025). USTIPs play a key role in developing smart city infrastructure through the adoption of cutting-edge digital technologies, smart mobility systems, and digital platforms that support smart urban ecosystems (John et al., 2025). Such innovations are often conceptualized not as isolated systems, but as integral elements that interact with the urban environment, land-use planning, and performance metrics.

2.3 Principles of Sustainable Urban Development

The framework also integrates key principles of sustainable urbanism, including compact urban form, environmental responsibility, social inclusiveness, and economic resilience (Callender, 2012; Kapucu et al., 2021). Spatially, USTIPs influence sustainability outcomes through mixed-use development, climate-responsive layouts, renewable energy integration, walkability, energy-efficient designs, and green infrastructure. Social sustainability is addressed through inclusive public spaces, knowledge-sharing environments, and employment opportunities, while economic sustainability is strengthened through innovation-driven growth and long-term urban adaptability.

2.4 Integrated Framework for Smart and Sustainable Cities

Based on the synthesis of these three perspectives, the proposed conceptual framework (Figure 1) positions emerging USTIPs as multi-dimensional hubs that integrate interrelated components, including (i) governance and policy structures, (ii) spatial and urban design configuration, (iii) technological and digital infrastructure, (iv) innovation and knowledge ecosystems, and (v) smart city and sustainability outcomes. The interactions between these components influence the extent to which USTIPs function as catalysts for smart and sustainable cities. The framework presented in Figure 1 supports the systematic review by providing an analytical outline for examining, comparing, and analyzing global USTIP models.

Figure 1. Conceptual Framework Exemplifying the Role of USTIPs in Smart and Sustainable Urban Development.

3. Research Methodology

This study adopted a systematic review of global literature to synthesize up-to-date research on University Science and Technology Innovation Parks (USTIPs). The literature search covered major academic databases, including Google Scholar, Web of Science, and Scopus, with a focus on peer-reviewed publications published between 2000 and 2025. The search keywords included “Science Parks,” “Innovation Parks,” “Smart Cities,” “University Science and Technology Innovation Parks,” “Sustainable Urban Development,” and “Innovation Hubs.”

The inclusion criteria comprised peer-reviewed journal articles, book chapters, and conference papers published in English. A two-stage screening process was employed. In the first stage, titles and abstracts were screened to assess relevance to USTIPs, urban design, sustainability, and innovation. In the second stage, full-text articles were reviewed with particular attention to discussions on governance structures, spatial configuration, technological infrastructure, and urban integration.

The systematic review enabled the synthesis of key findings related to USTIP typologies, governance models, technological infrastructure, urban design integration, and sustainability strategies, which formed the basis for developing the study’s conceptual framework. Given the heterogeneous nature of USTIP-related studies reported in the existing literature, a qualitative systematic synthesis approach was adopted.

4. Results and Discussion

4.1 Global Typologies of University Science and Technology Innovation Parks

University Science and Technology Innovation Parks (USTIPs) have evolved substantial over the past few decades (Klofsten et al., 2025; Lecluyse et al., 2019). This transformation reveals a diverse typology, spatial patterns, and innovations outcomes globally, leading to the classifications of science and innovation parks into four main types: (i) campus-integrated parks, which are directly linked to university campuses (Gomez & Derr, 2021); (ii) urban-integrated parks, which are integrated within cities and are closely related to local industries and environmental infrastructures (Myalkovsky et al., 2023); (iii) regional or peripheral parks, which promote regional innovation (Nauwelaers et al., 2019; Shan & He, 2025); and (iv) clustered innovation districts, which leverage on structured partnership between universities and industries (Kim et al., 2023; Rapetti et al., 2023). Each of these typologies reflects different levels of integration with the urban fabric, and impact on local socio-economic structure. Table 1 presents the global typologies of USTIPs, highlighting their spatial integration, key features, and examples from different regions.

Table 1: Typologies of Global University Science and Technology Innovation Parks.

	Typology	Description	Urban Integration	Key Features	Examples in Countries (Parks)
i.	Campus-Integrated Parks	Directly linked to university campus	Within campus environment	Research labs, incubators, student-led startups,	USA (Stanford Research Park), UK (Cambridge Science Park), China (Zhejiang University Science Park)
ii.	Urban-Integrated Parks	Embedded within city centers and urban cores	Urban core	Mixed-use development, public spaces, industry partnerships	Singapore (One-North), Germany (Munich Innovation Campus), Sweden (Kista Science City)
iii.	Regional/ Peripheral Parks	Located on urban fringe or peri-urban areas	Edge of city/ regional zone	Large land area, long-term growth,	India (Pune IT Park), Brazil (Campinas Tech Park), South Korea (Daedeok Innopolis)

				regional connectivity,	
iv.	Clustered Innovation Districts	Networked hubs linking multiple universities and industries	Multi-city/ regional clusters	Collaborative R&D, co-working learning spaces, transport connectivity	USA (Research Triangle Park), China (Zhongguancun Science Park, Beijing), France (Sophia Antipolis)

4.2 Governance Structures and Policy Models

University Science and Technology Innovation Parks (USTIPs) operate with different governance structures that often reflect the diverse level of partnership between universities, industries, and government institutions (Ribeiro et al., 2021; Sandoval Hamón et al., 2024). The Triple Helix Model is the dominant framework that emphases structural collaboration between the three actors i.e., universities, industries, and government in facilitating knowledge transfer, innovation growth, and economic development (Zadegan et al., 2025). However, the effectiveness of the governance structures depends not only on institutional frameworks but also key strategic planning tools that support government policies and integration with the urban environment. USTIPs often exhibit different governance structures. In university-led models, the university provides the research path, infrastructure, and management, while the industries serve mainly as collaborators (Kruger & Steyn, 2024; Sarpong et al., 2025). In contrast, the industry-led USTIPs are majorly driven by private sector investments, with the universities providing the talent and research support. The government models, are often public-private partnerships, rely on the national and local authorities to provide key infrastructures, policies, and incentives that facilitates collaboration between universities and industry (Ahmad & Alam, 2025). Such model influences the allocation of scarce resources, and innovation outcomes, which directly affect impact of USTIPs on urban sustainability and smart city integration. Table 2 presents the key governance structures and institutional frameworks of global USTIPs, highlighting the roles of universities, industry, and government in driving innovation ecosystems.

Table 2: Key Governance Structures and Institutional Frameworks of USTIPs.

	Type of Governance	**Key Institution**	**Role of Partners**	**Policy/ Strategic Support**	**Examples in Countries (Science Parks)**
i.	University-led	University	Industry as tenants and collaborators	University policies, funding, incubation programs	USA (Stanford Research Park), UK (Cambridge Science Park)
ii.	Industry-led	Private Sector	University provides research support and talent	Industry-led R&D funding, commercialization incentives	Japan (Tsukuba Science City), South Korea (Daedeok Innopolis)
iii.	Government-facilitated/ PPP	Government	University conducts research; Industry innovates	National innovation policies, grants, infrastructure support	China (Zhongguancun Science Park), Singapore (One-North)

4.3 Spatial Configuration, Urban Morphology, and City Integration

Recent Studies reveals that spatial configurations of USTIPs significantly influences sustainability outcomes (Ávila et al., 2025; Pan et al., 2024). USTIPs are not only clusters of research facilities; they serve as an innovation hub that require deliberate integration with the urban environment to maximize accessibility, connectivity, and socio-economic impact (Hrebennyk et al., 2024). Urban morphology features such as land-use patterns, density, and mixed-use development, plays a vital role in influencing innovation ecosystems, facilitating partnerships, and improving the utilization of public spaces (Huang et al., 2025). Research of USTIPs indicated diverse design features. The compact campus layouts have a dense arrangement of research laboratories, incubators, and academic buildings. These layouts foster strong interaction within such parks but often have limited connectivity to the larger urban environment. However, the urban-integrated layouts have the USTIPs integrated within city centers. Such layout helps in improving accessibility, knowledge transfer, and integration of public infrastructures. While, the regional or peripheral layout provide a comprehensive space for large-scale industrial clusters but requires an improved strategies to achieve connectivity with the city. Therefore, proper spatial planning is required to achieve a balance innovation outcomes, urban integration, and sustainable development. Table 3 present key spatial typologies, their characteristics, and their implications for urban integration and sustainability.

Table 3: Spatial Configuration and their Urban Integration in USTIPs.

	Typology	**Key Features**	**Urban Integration**	**Sustainability Linkages**	**Examples in Countries (Science Parks)**
i.	Compact Campus Layout	Dense arrangement of research labs, incubators, academic buildings	Limited external connectivity; strong internal collaboration	On-campus energy efficiency, green building design	USA (Stanford Research Park), UK (Cambridge Science Park)
ii.	Urban-Integrated Layout	Mixed-use, multi-purpose development within city center	High accessibility, integration with transport and public spaces	Smart mobility, data-driven urban services	Singapore (One-North), Germany (Munich Innovation Campus)
iii.	Regional/ Peripheral Layout	Large land area, industrial clusters, R&D zones	Requires transport infrastructure; regional connectivity	Renewable energy integration, eco-friendly planning	India (Pune IT Park), China (Zhejiang University Science Park)

4.4 Technological Infrastructure and Smart City Linkages

Technological infrastructure serves as a key element of USTIPs, which influences their capacity to foster innovation and incorporate smart city initiatives (Jiao et al., 2025; Varzeshi et al., 2026). Most 21st century USTIPs has increasingly adopted digital platforms, Internet of Things (IoT), artificial intelligence (AI) systems, and other data-driven tools to improve productivity, facilitate knowledge transfer, and foster environmental responsiveness (Kumar et al., 2024b; Rashid & Kausik, 2024). Such infrastructures not only enhance research and entrepreneurship but also strengthen the urban connectivity of most USTIPs with its surrounding environment. The adoption of such technologies varies significantly on the typologies of the park and the local urban context. USTIPs with campus-integrated layout focus more on research laboratories, high-speed networks, and university-led innovation hubs, while USTIPS with an urban-integrated layout often focus on smart mobility systems, digital platforms for public engagement, and collaborative spaces embedded within cities. Regional or peripheral parks prioritize having large-scale industrial technologies and logistics platforms that requires strong digital connectivity for its integration in cities. Table 4 exemplifies key technological infrastructure deployed in various USTIP typologies and their role in facilitating smart city initiatives.

Table 4: Key Technologies and their Smart City Linkages in USTIPs.

	Typology	Key Technologies	Smart City Integration	Examples in Countries (Cities)
i.	Campus-Integrated	Research labs, high-speed networks, innovation platforms	On-campus AI, digital knowledge-sharing systems	USA (Stanford Research Park), UK (Cambridge Science Park)
ii.	Urban-Integrated	Smart mobility, digital collaboration platforms, IoT	Urban analytics, smart transportation, public engagement	Singapore (One-North), Germany (Munich Innovation Campus)
iii.	Regional/ Peripheral	Industrial technologies, logistics platforms, cloud-based systems	Integration with urban centers, regional smart grids	India (Pune IT Park), China (Zhejiang University Science Park)

4.5 USTIPs and Sustainable Urban Development Outcomes

USTIPs contribute substantially to sustainable urban development through several environmental, social, and economic aspects, aligning closely with various United Nations Sustainable Development Goals (SDGs).

Environmentally, USTIPs facilitate SDG 7 i.e., Affordable and Clean Energy and SDG 13 i.e., Climate Action by promoting the adoption of energy-efficient technologies for buildings, integration of renewable energy systems, and utilization of climate-responsive design strategies. Also, the incorporation of green infrastructure, walkable spaces, and compact urban forms contributes towards achieving SDG 11 i.e., Sustainable Cities and Communities by reducing environmental impacts and improving urban resilience.

From the social dimension, USTIPs support the strengthening of SDG 4 i.e., Quality Education and SDG 9 i.e., Industry, Innovation, and Infrastructure by facilitating knowledge transfer, research commercialization, and innovation-driven learning environments. The provision of an inclusive collaborative public spaces, interactive working environments, and other employment opportunities aids in attaining SDG 8 i.e., Decent Work and Economic Growth and promotes social inclusiveness and community engagement. These social aspects strengthen the role of USTIPs as vital hubs for knowledge transfer and human capital development.

Lastly, USTIPs contribute economically to SDG 8 and SDG 9 by fostering innovation-led economic growth, attracting direct investment, and improving regional competitiveness. The integration of smart technologies, digital infrastructure, and innovation ecosystems facilitates the rapid transition of cities to knowledge-based economies with long-term resilience and urban adaptability. Thus, these outcomes demonstrate the ability of USTIPs to strengthen global sustainability agendas at the urban scale by aligning innovation, spatial planning, and governance structures with specific SDGs. The relationship between USTIPs sustainability outcomes and the specific SDGs are summarized in Table 5.

Table 5: Sustainability aspect of USTIPs and their contributions to SDGs.

	Aspect	USTIP Contributions	Specific SDGs
i.	Environmental sustainability	Adoption of energy-efficient building systems, integration of renewable energy, climate-responsive design strategies, and integration of green infrastructure and compact forms.	SDG 7 (Affordable and Clean Energy); SDG 11 (Sustainable Cities and Communities); SDG 13 (Climate Action)
ii.	Social sustainability	Knowledge transfer, research commercialization, innovation-driven learning environments, inclusive public spaces, and collaborative work environments, enormous employment opportunities	SDG 4 (Quality Education); SDG 8 (Decent Work and Economic Growth); SDG 9 (Industry, Innovation, and Infrastructure)
iii.	Economic sustainability	Innovation-led economic growth, attraction of investment, regional competitiveness, knowledge-based economies, and integration of digital smart technologies.	SDG 8 (Decent Work and Economic Growth); SDG 9 (Industry, Innovation, and Infrastructure)

4.6 Implications for Urban Planning and Design

The findings of this study have significant implications for urban planners, and policy-makers. The review of global USTIPs highlight the vital need for synergy between urban design, spatial planning, and governance structures with numerous innovational and technological infrastructure in creating a functional and sustainable urban systems. For USTIPS to be successful, careful considerations are required for achieving proper accessibility, connectivity, mixed-use development, and public space integration, with policy frameworks that fosters partnership between universities, industry, and government. Therefore, designing USTIPs as urban innovation parks rather than the traditional isolated parks ensures a functional and spatially innovative ecosystems within cities, promoting knowledge transfers, social inclusiveness, and environmental sustainability. Similarly, integrating smart technologies within the urban fabric helps cities optimize resources, by creating an adaptive and sustainable urban environment. Such outcomes serve as a crucial strategy for emerging cities seeking to leverage university-driven innovation for smart and sustainable urban development.

5. Conclusion

This study systematically reviewed global literature on University Science and Technology Innovation Parks (USTIPs), examining their key roles as catalysts for smart and sustainable cities. The findings establish the transformation of USTIPs from the traditional isolated parks into integrated urban hubs that are shaped by different governance models, spatial configurations, technological infrastructure, and innovational frameworks. The study revealed that effective USTIPs are often characterized by a strong collaboration between universities, industry, and government, alongside deliberate spatial integration with urban environment and the utilization of digital smart technologies. The incorporation of these factors helps USTIPs contribute to environmental sustainability, social inclusiveness, and innovation-driven development. The review further showed that USTIPs with integrated urban layouts aids in achieving smart cities and sustainable urban development. Therefore, the outcome of this study is a conceptual framework linking theory of innovation with urban planning model. Future research could focus on empirical case studies and spatial performance assessments, particularly in rapidly urbanizing regions, to further validate and refine the specific roles of USTIPs in achieving sustainable urban development.

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The author(s) report no conflicts of interest.

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