

Article

Uncovering Obstacles and Limitations of Smartness: A Cross-Case Analysis of Smart Cities and Smart Real Estate

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Highlights

What are the main findings?

- This research has identified six interrelated categories of limitations that prevent smart cities and smart real estate from achieving their full potential: conceptual and strategic; technological and infrastructural; governance and institutional; economic and financial; social and ethical; and environmental factors.
- The comparative assessment of Toronto, Songdo, NEOM, and Barcelona found that governance, public trust, social acceptance, and institutional coordination are as important as technological capacity.

What are the implications of the main findings?

- Smartness should be viewed as an integrated technological, institutional, social, economic, and environmental capacity rather than just as technology implementation.
- Policymakers, developers, and technology providers should emphasize transparent governance, public participation, interoperability, privacy-by-design, financial sustainability, and life cycle assessment.

Abstract

Smart cities and smart real estate are increasingly used to enhance urban efficiency, sustainability, and quality of life. Nevertheless, their implementation is hindered by interconnected challenges across concepts, technology, governance, economics, society, ethics, and the environment. Thus, this paper examines how and why interconnected limitations constrain the smartness of smart city and smart real estate initiatives and identifies the governance and implementation responses revealed by cross-case comparison. The analysis of secondary academic sources, policy papers, standards, and industry reports compares Toronto, Songdo, NEOM, and Barcelona. The results identify six categories of limitations: conceptual and strategic; technological and infrastructural; governance and institutional; economic and financial; social and ethical; and environmental. The analysis shows that the challenges facing these initiatives go beyond technology alone and include ambiguous definitions of smartness, poor governance, limited public involvement, privacy and surveillance risks, high implementation and maintenance costs, interoperability issues, and unverified assumptions that technological advancement will deliver sustainability. The comparison of cases highlights that the success of these initiatives depends on effective governance, responsible data management, public trust, financial feasibility, institutional coordination, and a life cycle approach. The study concludes that smartness should be understood as an integrated institutional, economic, social, technological, and environmental capacity rather than as the mere adoption of digital technologies.



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Keywords: smart cities; smart real estate; smart-washing; smart city limitations; smart city challenges; implementation barriers

1. Introduction

Governments are increasingly focusing on developing smart cities by integrating technologies to improve infrastructure, city services, environmental performance, and governance. Smart real estate (SRE) is closely associated with the development of smart cities and operates within a similar framework. Nonetheless, the SRE framework underscores the significance of modern technology, particularly in the development of sites and entire neighborhoods, leading to greater efficiency, comfort, security, sustainability, and enhanced overall experience. Although both approaches have the potential to improve the urban environment, documented implementation challenges, governance issues, social, financial, and life cycle challenges remain, raising questions about the efficiency, fairness, and sustainability of smart city (SC) and SRE processes.

SCs are commonly associated with information and communication technologies, sensors, data platforms, artificial intelligence, and digital infrastructure used to improve urban management and decision-making [1,2]. Nevertheless, conceptual and empirical smart city studies show that SC discourses frequently overvalue the role of technology while underestimating the complexity of social, institutional, ethical, and political aspects [3–5]. Along these lines, many smart systems become less efficient not because of a lack of technology but because of poor governance, unequal access, insufficient integration, or a mismatch with end users' requirements.

The main issue in the field that remains is the ambiguity of the term “smartness”, which complicates evaluation, benchmarking, and accountability. The term SC lacks a single definition, as it is defined differently by specialists across various fields [2,6]. SRE also contributes to the debate over what defines an SC; it includes buildings, districts, and real estate assets, where smart technologies influence energy use, data generation, asset management, user experience, and life cycle performance [7,8]. Recent studies show that smart technologies can be beneficial throughout the real estate cycle, from land selection and construction to operation and maintenance [9]. However, these technologies also pose risks, including high implementation costs, potential cybersecurity vulnerabilities, vendor dependency, limited interoperability, unclear data ownership, rapid technological obsolescence, and privacy concerns. Therefore, SRE should not be examined only as an efficiency-enhancing tool but also as a site where broader SC limitations become visible.

SCs and SRE may reduce resource consumption, improve operational efficiency, enhance waste management, and support better infrastructure management [1,2,9]. However, these technologies do not automatically solve fundamental urban problems such as poor land-use planning, inadequate housing, weak governance, social inequality, or low-quality urban design [10–12].

Accordingly, this paper examines the limitations and obstacles to SCs and SREs through a literature review and case study analysis. A major goal is to identify the main categories of limitations, evaluate their impact across the selected case studies, and propose measures to mitigate them. Unlike previous studies that primarily discuss individual technological, governance, or sustainability challenges, this study develops an integrated analytical framework that classifies limitations across six categories, compares their manifestation across four internationally recognized smart city initiatives, and proposes implementation-oriented recommendations applicable to both smart cities and smart real estate.

The study is guided by one main research question: Which constraints affect the achievement of smartness in smart city and smart real estate environments, and how do those constraints relate to different governance and development systems? Three analytical sub-questions examine which limitations are primary or secondary in each case; how governance and development arrangements shape their mechanisms, severity, and scale; and which actors are responsible for mitigation and what financial or non-financial value should be evaluated.

This paper is structured as follows: Section 2 presents the background and theoretical positioning. Section 3 explains the methodology. Section 4 reports the case and cross-case results. Section 5 interprets the findings and develops actor-specific recommendations. Section 6 answers the research question, summarizes the contributions, and states the policy implications.

2. Background

2.1. Definitions

A significant obstacle in the study of SCs is the absence of a common definition of what an SC is. Consequently, the term is often used inconsistently across academic, governmental, and the commercial literature. Some definitions highlight technical architecture and digital management, while others stress sustainability, living standards, development, or participatory governance, as each expert defines it based on their field [1–4].

The early literature commonly associated smartness with the use of information and communication technologies to improve urban systems and services. Caragliu et al. (2011) define SCs as places with both human social capital and investment in traditional infrastructure and modern information and communication technologies, where these investments lead to sustainable economic growth and a high quality of life through participatory governance [2]. As described by Batty et al. (2012), the growing significance of digital technologies, data, and urban intelligence in addressing the complexity of city systems underlies the term SC. Notably, several critical theorists maintain that it is unwise to think of smartness solely in terms of technology [1]. Hollands (2008) warns that the term SC may become a marketing strategy if it is not tied to progressive urban development, social inclusion, and democratic governance [3]. According to Kitchin (2015), the vagueness of definitions negatively influences evaluation, accountability, and policy coherence [4].

This vagueness opens the door to what may be called smart-washing, because smartness is regarded as a brand, a source of financing, and a means of attracting investment rather than as evidence of real improvements in technology, social outcomes, environmental performance, or governance. In other words, a city or a district may claim to be smart without relevant benchmarks, implementation standards, or accountability [3,10,13,14].

In this study, an SC is defined as a city that uses smart technologies to make its interrelated sectors and critical components—governance, people, energy, infrastructure, real estate, information, and environment—more intelligent, sustainable, interconnected, and efficient [15]. It also shifts the focus away from isolated technological adoption and toward the integration of multiple urban sectors.

Another major point to address is that smartness should be distinguished from sustainability. It is still possible to attain sustainability goals without being technologically smart, for instance, by using passive design and minimizing resource consumption. At the same time, a highly digitalized city or building is not automatically sustainable if its technologies increase energy demand, produce electronic waste, reinforce social exclusion, or fail to generate measurable environmental benefits. In this sense, sustainability may be one possible outcome of smart development, but being smart does not necessarily equal being sustainable [16,17]. Additionally, there is a distinction between smart buildings and SRE.

The term “smart buildings” usually refers to individual assets that use sensors, automation, and building management systems to improve operational performance, energy efficiency, comfort, and safety [18]. SRE is broader because it considers the full real estate life cycle, from land development and project conception to post-vacancy decisions [15].

2.2. Smart Real Estate in the Context of Smart Cities

SRE is an important component of SC development because buildings, districts, and real estate assets are among the main physical spaces where smart technologies are implemented and experienced. While SCs operate at the urban scale, SRE operates at the asset, project, district, and life cycle scales. This means that the performance of an SC is partly connected to how effectively its real estate assets are planned, developed, and integrated into wider urban systems [19,20].

These dynamics are important because real estate involves energy consumption, data generation, land-use change, and environmental impacts. Thus, implementing smart technologies, such as IoT sensors, artificial intelligence (AI), digital twins, and predictive analytics, can improve decision-making, management, energy efficiency, comfort, security, and asset efficiency [7,18,21]. However, these technologies create broader urban value only when they are connected to city-level infrastructure, governance systems, data platforms, and sustainability strategies.

The integration of both levels also creates several limitations. Building-level systems may not be interoperable with municipal platforms, smart technologies may be adopted mainly for branding or market differentiation, and developers may face high implementation costs, uncertain return on investment, data governance concerns, and rapid technological obsolescence [7,9].

2.3. Advantages and Disadvantages of Smart Cities and Smart Real Estate

SCs and SREs are promoted as ways to improve urban efficiency, sustainability, economic competitiveness, and quality of life. The integration of digital technologies, data analytics, sensors, automation technologies, and interconnected infrastructure creates smart systems with urban management capabilities that enhance the efficient use of resources [1,20]. At the city level, smart technologies support mobility, energy management, waste management, public safety, environmental monitoring, and digital governance [19]. At the level of real estate, these tools can enhance the operational effectiveness of buildings and their users [18,21].

One major advantage of SCs is their potential to improve operational efficiency. Internet of Things systems, smart grids, intelligent transport systems, and urban data platforms allow cities to monitor infrastructure, allocate resources, and respond more quickly to changing urban conditions [19,20]. The implementation of smart technologies can enhance the decision-making process throughout the real estate life cycle [9,21]. These technologies can improve planning, construction, operation, maintenance, and redevelopment. Both levels also contribute to improving sustainability through the use of smart technologies, which lead to reduced energy consumption, optimized water use, support for renewable energy systems, waste reduction, and improved environmental performance [16].

While SCs and SRE offer numerous benefits, they also have many limitations. Privacy and surveillance rank among the top concerns. Smart systems rely on collecting large amounts of continuous data through an array of tools—sensors, cameras, access systems, mobile applications, and Internet of Things devices—as part of their operation, which could result in decreased public trust and a potential for data theft or abuse [22,23]. Economic and governance-related factors also undermine their viability. The initial development of smart infrastructure requires substantial capital investment in engineering and proprietary

technical expertise as well as ongoing support, maintenance, and upgrades after completion. Consequently, the costs of SC infrastructure could render them economically infeasible for smaller municipalities or less profitable real estate markets [24]. Moreover, various parties are often involved in SC projects, including local authorities, technology providers, telecommunications and construction organizations, and developers, who often lack the governance structures to manage them. This increases the likelihood of project failure [5,13].

Similarly, adopting advanced technology does not ensure sustainable development, even when the technologies deployed are state-of-the-art. In this regard, a city or region may be equipped with the latest technological developments but still fall short in terms of social connectivity, sustainability, inclusion, and participation. Moreover, the critical literature about SCs argues that if a city's "smartness" is used for branding or corporate marketing, and not linked to democratic processes, social inclusion, or measurable benefits to society, the city's use of the terms "smart city" and "smart district" could be misleading [3,14].

SCs and SRE create significant opportunities as well as highly complex technological, economic, governance, ethical, social, and environmental risks associated with being "smart". Consequently, these limitations show that simply being "smart" is not enough and, therefore, benefits related to the successful implementation of "smartness" depend on having clear objectives, an integrated approach to governance and ethical data usage, the accommodation of diversity in planning, financial affordability, systems interoperability, and performing life cycle sustainability assessments.

2.4. Theoretical Positioning, Research Gap, and Contribution

The theoretical framework used in this research draws on three complementary perspectives. Critical smart urbanism helps identify the stakeholders and interests embedded in smart city narratives, applications, surveillance, and participation processes [4,5,10,12,14,22,25–27]. Sociotechnical studies explain why smart systems function only when technologies, organizations, and users are aligned [28–32]. Institutional capacity studies focus on power, rules, accountability, learning, and collaboration [28,33–39]. Taken together, these perspectives show that technology becomes an effective urban capacity when rights, obligations, incentives, and public goals are aligned.

Established frameworks indicate that SC initiatives are multidimensional [6,7,40,41], that governance is a central research domain [28,33,34,38], and that assessment systems contain conceptual and methodological weaknesses [39,42–45]. Recent research also classifies stakeholder types and interactions, data governance models, city types, smart-washing, and adverse technological effects [27–30,36–39,46–51]. The gap is therefore not the absence of barrier classifications, and novelty does not arise merely from combining six categories with four cases.

The paper uses this combined lens to compare how limitations interact across governance and development models and then traces their implications from the city to the real estate life cycle. The resulting diagnostic complements existing smart city taxonomies; it does not claim to replace them.

3. Materials and Methods

This study adopts a qualitative exploratory approach to examine the limitations and obstacles associated with SCs and SRE. It combines analysis of the existing academic literature, policy documents, industry publications, and comparative case studies. This approach is suitable because the limitations are multidimensional and encompass technical, governance, economic, social, ethical, environmental, and real estate issues from both smart city and smart real estate perspectives.

3.1. Research Approach and Sources

The existing literature was used to develop the conceptual basis for identifying and categorizing limitations. Reviewed sources included peer-reviewed journal articles, conference proceedings, books, institutional reports, municipal documents, planning evaluations, and selected industry publications. Sources were identified through Scopus, Web of Science, Google Scholar, ScienceDirect, the TU Dortmund University library, and Emerald. The search focused on limitations of SCs, SRE, smart buildings, smart infrastructure, data ethics, implementation barriers, sustainability, and smart urbanism. The literature was used to identify recurring limitations and support the development of the analytical framework applied to the case studies.

All evidence used in the study is secondary. The documentary corpus covers 2008 to 25 August 2026; it includes recent research on adverse technological effects, smart-washing, data governance, people-centered governance, NEOM, and ecological critique [27,31,35,36,38,39,46–52]. The searches combined SC, smart urbanism, SRE, and smart building with terms concerning limitations, governance, privacy, interoperability, finance, sustainability, measurement, indicators, and the four case names. Supplementary Table S1 reports the full protocol and selection logic.

All of the documents that meet one of the following criteria were included: characterized or critically analyzed the notion of SCs, smart governance, SRE, and smart buildings; defined any observable limitation, causal mechanism, or method of evaluation; provided substantive evidence on at least one selected case; or established a relevant standard or policy principle. Purely promotional, duplicative, generic, or technologically isolated material was excluded. Official project material was used to establish stated objectives, but not as the sole basis for critical assessment. The final cited corpus contains 64 sources. This study is a focused critical review, rather than a systematic review; it does not claim exhaustive coverage, statistical representativeness, or PRISMA-style screening procedures.

3.2. Analytical Framework for Limitations

A conceptual framework was developed to classify the limitations, challenges, and obstacles associated with SCs and SRE. The SC evaluation literature, studies on SRE integration, sustainability research, and the critical urbanism literature informed the framework. It was designed to organize the identified limitations into clear categories and enable comparison across different cases and scales. The framework classifies limitations into six main categories as presented in Figure 1.

To generate the deductive seed codes, multidimensional frameworks of SC, governance, assessment, sustainability, adverse effects, and SRE were utilized [7–9,15–18,21,28–30,33,34,36–44,46–49,53]. Inductive refinement grouped case-specific manifestations and applied boundary rules to reduce double coding. For example, interoperability is technological when the mechanism involves incompatible architecture, but governance-related when the mechanism is devoid of authority or procurement coordination; high cost is economic, whereas unequal access produced by cost is social and ethical.

As shown in Figure 1, the identified limitations are classified into six main categories: conceptual and strategic; technological and infrastructural; governance and institutional; economic and financial; social and ethical; and environmental. Severity, scope, prevalence, and causal mechanism are evaluation dimensions applied to every category; they are not additional categories or conceptual types. Severity is rated using the rules in Section 3.5; scope identifies the limitation at the city, cross-scalar, or SRE/life cycle level; and prevalence records the primary and secondary case patterns. This separation enables consistent comparison without conflating the nature of a limitation with its seriousness or location.

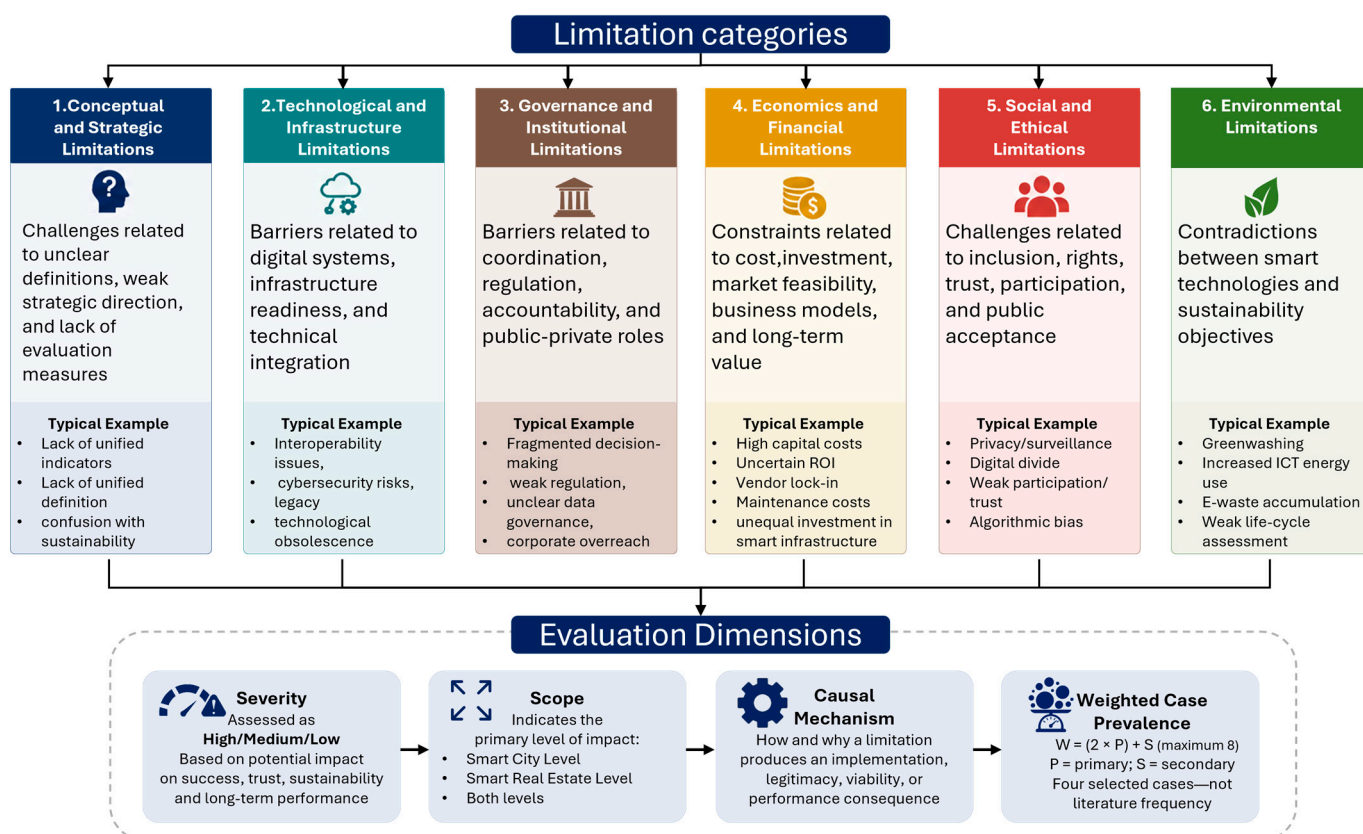


Figure 1. Conceptual framework for classifying smart city and smart real estate limitations. The six categories synthesize multidimensional, governance, assessment, sustainability, adverse-effect, and SRE frameworks. Author, 2026.

3.3. Coding Protocol, Consistency, Bias Mitigation, and Reflexivity

The case material and the supporting literature were analyzed with thematic coding. A hybrid deductive–inductive approach was adopted, with deductive codes derived from the existing literature on SCs, digital governance, sustainability, and real estate development, and inductive coding used to capture context-specific and/or unexpected limitations arising from the sample cases. The coded material was compiled into six thematic categories corresponding to the analytical framework. Each category was further divided into subgroups, such as interoperability, data governance, public trust, privacy, cost, technological obsolescence, and sustainability claims.

The source, date, source type, case, category, primary manifestation, causal mechanism, consequence, city/SRE relevance, and evidentiary status were all recorded for each evidence item. A primary manifestation had to be central to the case narrative, supported by at least two independent sources or source types where available, and materially connected to implementation, legitimacy, viability, or performance. A secondary manifestation was present but not central, less consequential, or supported more provisionally. The same definitions were applied across all four cases, while contrary or mitigating evidence was retained rather than forced into the coding scheme. More details on coding and rating rules are provided in Supplementary Table S2.

Formal independent double coding and inter-coder reliability statistics were not conducted and are therefore not reported. Interpretive bias was mitigated through explicit definitions and boundary rules, source triangulation, separation of promotional claims from independent evaluation, negative-case searching, and a second internal consistency check of the case matrix. The SRE lens was informed by established city real estate evaluation frameworks [7,8,15] which provide domain grounding for interpreting the relationship be-

tween smart city strategies and real estate life cycle decisions. The coding rules, comparison logic, and absence of independent reliability testing are stated explicitly and acknowledged in Section 5.5.

3.4. Case Study Selection and Analysis

The second stage of the methodology involved selecting and analyzing four case studies to illustrate the wide range of outcomes from implementing SC and SRE initiatives, ranging from successes to failures. A comparative case study analysis was employed to understand how the identified limitations manifest in practice within the cases' respective contexts. The first criterion required that each case study feature a significant SC and/or SRE initiative with explicit goals oriented toward one or more of the following: technology innovation, increased efficiency, sustainability, and urban transformation. The second criterion required that each case study exhibit diversity in its geographic context, governance model, degree of development, and urban typology. The third criterion restricted the selection of case studies to those for which documents and/or references were available that provided evidence of the limitations, critiques, or challenges associated with implementation and/or operation. Finally, preference was given to case studies with substantial publicly available information, including the academic literature, policy documents, project reports, and professional evaluations.

The cases provide maximum variation rather than statistical representativeness. Toronto represents a contested, corporate-led district proposal; Songdo is a built, technology- and real estate-led new city; NEOM is an evolving, centralized megaproject; and Barcelona is an existing city with citizen- and municipality-led digital governance. Their differences in maturity, political economy, scale, and governance make mechanism comparison informative but preclude direct performance ranking.

Figure 2 summarizes the four-step workflow. The cases were selected for their relevance to SC or SRE development, contrasting contexts, documented limitations, and adequate source material. Given the limitations of the evidence and the cases, the exploratory comparison aims to reveal specific mechanisms and recurring patterns rather than produce a single performance ranking. The final step assesses each category's severity, scope, and case prevalence.

As a result, four case studies were selected: Toronto, Songdo, NEOM, and Barcelona. Table 1 summarizes their locations, development models, selection rationales, and relevance to the study. The Toronto case study illustrates the consequences of poorly defined data governance and the lack of clarity about the roles of private sector partners in developing and transacting within a privately led smart district. Songdo represents the consequences of planning for a connected society at the expense of people's connectedness. NEOM, as a smart megaproject, is particularly controversial because of governance, ethical, environmental, and participation concerns. Meanwhile, Barcelona can be seen as a citizen-centric SC but still faces the same problems of scaling, financing, and implementation [32,45,50,54–58].

The cases were examined using a variety of the academic literature, official case documentation, and other sources. Furthermore, thematic content analysis was employed to analyze each case's data, identify the major limitations of each case, code them according to the theoretical framework used for analysis, and then conduct a cross-case comparison to identify patterns or differences across cases. In doing so, this provided a considered understanding of the limitations at both the metropolitan and SRE levels, including costs, interoperability, public trust, governance, and data management.

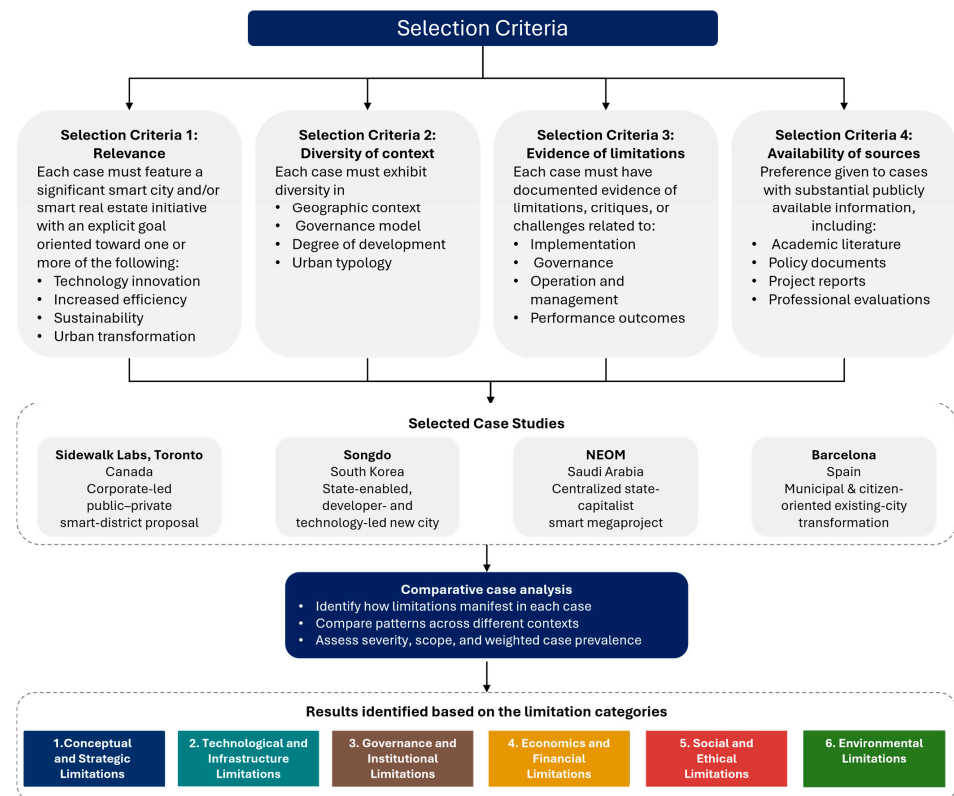


Figure 2. Focused critical review and structured comparative case-analysis workflow. Author, 2026.

Table 1. Case study selection logic, evidence triangulation, and comparison limits. Author, 2026.

Case	Development and Governance Model	Selection Rationale	Relevance to the Study	Comparison Limit
Toronto/ Sidewalk Labs, Canada	Corporate-led, public–private smart district proposal	High-profile cancellation following disputes over data authority, corporate scope, and public legitimacy.	Unclear data governance, challenges with public–private partnerships (PPPs), issues surrounding corporate expansion, and lack of public trust.	Proposal did not reach full construction or operation.
Songdo, South Korea	State-enabled, developer- and technology-led new city	Built example integrating advanced infrastructure with real estate-led master planning.	Low levels of social vibrancy, minimal social engagement, real estate-driven development, high implementation costs, low adoption and acceptance.	Longer operational history but different national institutions.
NEOM, Saudi Arabia	Centralized state-capitalist smart megaproject	Extreme scale links digital ambition, real estate development, feasibility, rights, and environmental claims.	Top-down governance systems; concerns around displacement of residents; human rights issues; environmental incongruity; techno-utopian planning and placemaking.	Evolving project; outcomes and plans remain uncertain.
Barcelona, Spain	Municipal and citizen-oriented transformation of an existing city	Contrasting public value and data sovereignty orientation with implementation and scaling constraints.	Obstacles include issues related to scale, insufficient funding, failure to ensure interoperability, and insufficient coordination among the institutions involved.	Incremental existing city programs differ from greenfield projects.

Triangulation combined peer-reviewed case studies with legislation, policy papers, institutional reports, and civil society documents. Toronto is studied through legal and governance analysis and research on data trust and acceptance [45,49,54]; Songdo through political–economy research and technology firm analysis [50,51]; NEOM through feasi-

bility, state capitalism, urban AI, and human rights sources [31,57,59,60]; and Barcelona through innovation, implementation, and data governance studies [32,58,61]. Conflicting interpretations are treated as evidence of contested claims rather than averaged into false agreement.

3.5. Severity, Scope, Case Prevalence, and Consistency Rules

Severity is treated as an ordinal analytical judgment rather than a probability estimate. A score of 1 (low) indicates a localized, reversible issue with a minor effect on core value; 2 (moderate) indicates a persistent or multi-domain issue that affects core value but remains mitigable; and 3 (high) indicates a major threat to legitimacy, safety, rights, viability, or core performance. A stated mechanism and consequence must support a score of 3. Scope is coded as 1 for the city or public system level, 2 for both city and real estate levels, and 3 for the project, building, or development life cycle level. Scope locates a limitation but does not measure its importance.

Primary frequency is the number of cases in which a category is coded primary (P/4); secondary frequency is S/4. Weighted case prevalence is calculated as $W = (2 \times P) + S$, where P and S are the respective numbers of primary and secondary case designations; the maximum is 8. This score summarizes coverage across the four cases and sizes the bubbles in Figure 3; it is not a literature-mention frequency. Severity is assigned independently from the documented mechanism and consequence and is not calculated from prevalence. No composite overall impact score is calculated by multiplying ordinal ratings. Supplementary Table S4 provides a complete arithmetic audit and a worked example. These rules are summarized in Table 2.

Table 2. Operational codebook, category boundaries, severity basis, and dominant scope. The same definitions are applied to all four cases. Author, 2026.

Category	Operational Definition and Boundary	Illustrative Indicators	Severity Basis	Dominant Scope
Conceptual and strategic	Ambiguity or misalignment in goals, definitions, success criteria, or theory of change; exclude implementation failures with an otherwise clear goal.	Undefined smartness; input-only indicators; smart-washing; conflation of smart and sustainable	High when ambiguity legitimates major investment or prevents accountability	Both
Technological and infrastructural	Limits arising from architecture, integration, security, reliability, legacy systems, or technical life cycle.	Interoperability gaps; cyber vulnerabilities; obsolescence; weak data quality	High when core services, safety, or cross-system operation are threatened	Both
Governance and institutional	Limits in authority, rules, accountability, coordination, procurement, or organizational capacity.	Unclear data rights; fragmented mandates; corporate overreach; weak oversight	High when legitimacy, rights, or delivery authority is compromised	City-dominant
Economic and financial	Capital, operating, financing, affordability, procurement, or value-realization constraints.	High capex; uncertain total cost/ROI; vendor lock-in; unequal investment	Moderate unless viability or equitable access is systemically threatened	Both/SRE
Social and ethical	Limits affecting rights, trust, participation, access, distribution, or human agency.	Privacy; surveillance; digital divide; algorithmic bias; weak participation	High when rights, inclusion, legitimacy, or adoption are materially affected	Both
Environmental	Life cycle resource, energy, carbon, ecological, waste, or rebound effects.	ICT energy demand; embodied impacts; e-waste; greenwashing; rebound	Moderate to high depending on scale, irreversibility, and verification	Both, especially SRE

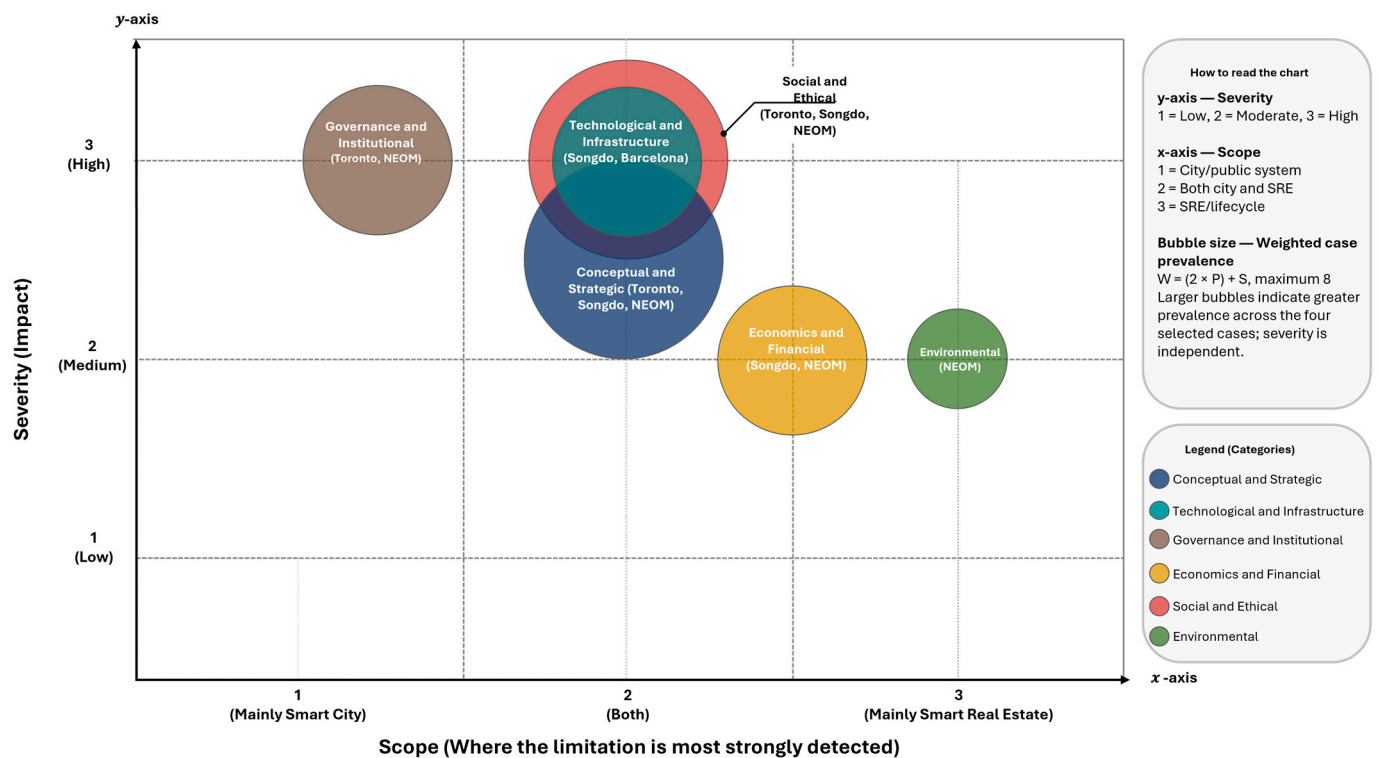


Figure 3. The severity and scope of limitation. The severity uses the anchored 1–3 rubric; scope: 1 = city/public system, 2 = both city and SRE, and 3 = SRE/life cycle; weighted prevalence equals $W = (2 \times P) + S$, maximum 8. Small horizontal offsets separate overlapping bubbles for legibility without changing their coded scope. More details are provided in Supplementary Table S4. Author, 2026.

4. Results

The analysis focused on identifying six key categories of limitations affecting SCs and SRE projects, based on the reviewed literature and selected case examples. These limitations are prevalent in the literature and in the reviewed case studies. However, the level of impact varies with the project's scale, the governance model, public acceptance, and the degree of integration between city systems and real estate assets.

Table 3 demonstrates that non-technological limitations are among the most serious limitations. In particular, the governance frameworks of the respective projects, the level of public trust, the ethical use of data, the ambiguity of concepts associated with smart urban development, and the misuse of the term “smart” significantly impact the legitimacy and long-term value of smart initiatives at both levels. These findings support critiques that smart urbanization can be fragile when the notion of digital innovation lacks clear definition, public accountability, and measurable outcomes [3–5,11].

Table 3. Main categories of limitations affecting smart cities and smart real estate. Author, 2026.

Category	Key Limitations	Main Affected Level	Impact Level
Conceptual and strategic	Unclear definition of smartness; confusion between smart and sustainable; no common indicators; risk of smart-washing.	Both	Medium–High
Technological and infrastructural	Interoperability gaps; cybersecurity risks; legacy systems; data integration problems; technological obsolescence.	Both	High
Governance and institutional	Fragmented governance; ambiguous data ownership; weak regulation; corporate overreach; poor public–private coordination.	SC	High

Table 3. *Cont.*

Category	Key Limitations	Main Affected Level	Impact Level
Economic and financial	High capital investment; uncertain return on investment (ROI); vendor lock-in; long-term maintenance costs; unequal investment in smart infrastructure.	Both	Medium
Social and ethical	Privacy concerns; surveillance; digital divide; poor citizen engagement; lack of public trust; algorithmic bias.	Both	High
Environmental	E-waste; increased Information and Communication Technology energy demand; greenwashing; weak life cycle assessment; unclear sustainability benefits.	Both, especially SRE	Medium

4.1. Case Study Findings

4.1.1. Toronto/Sidewalk Labs

The Sidewalk Labs project in Toronto illustrates the risks associated with corporate-led SC development. It raises questions about data governance, privacy, public accountability, and the influence of technology companies on urban policy development. These concerns contributed to sustained public opposition and undermined project legitimacy; the project was ultimately withdrawn [45]. This case demonstrates the potential for failure of smart cities and smart districts when data ownership, consent, and governance responsibilities are not clearly defined.

Uniform framework application: conceptual–strategic, governance–institutional, and social–ethical limitations are primary; technological and economic issues are secondary. The causal chain runs from expansive platform and district ambition, through unresolved public authority and data rights, to declining trust and political feasibility [45,49,54]. At the SRE scale, data ownership, permitted reuse, retention, public–realm interfaces, and exit rights must be settled before building management and platform contracts create lock-in.

4.1.2. Songdo

The Songdo case demonstrates the limits of SC models. Despite having modern infrastructure, automated systems, and smart buildings, Songdo lacks social vibrancy, has low community participation, and fails to offer the experience of human-scale urban living [11,50]. This indicates that advanced infrastructure does not necessarily result in a livable urban environment that supports social interaction or is socially supported.

Uniform framework application: conceptual–strategic, technological–infrastructural, economic–financial, and social–ethical limitations are primary, while governance is secondary. Technology- and property-led master planning enabled delivery but provided weaker feedback from evolving social practices and demand [50,51]. For SRE, occupancy, social diversity, adaptability, service usability, maintenance, and the capacity to update proprietary systems influence long-term value as much as the initial technical specification.

4.1.3. NEOM

The risks in the NEOM project stem from centralized megaprojects driven by smart technology. Although NEOM sets ambitious technological and environmental goals, concerns remain about transparency, displacement, environmental impacts, and human rights [57]. This illustrates how large-scale smart infrastructure and real estate projects can face significant legitimacy concerns.

Uniform framework application: conceptual–strategic, governance–institutional, economic–financial, social–ethical, and environmental limitations are primary; technological dependence is secondary. Centralized authority and exceptional scale reduce the need for external correction of technical, financial, rights, and life cycle assumptions [31,57,59,60].

The SRE implications include land assembly, phasing, embodied carbon, water and energy systems, future demand, operation of unprecedented structures, and the distribution of risk among public capital, developers, investors, users, and affected communities. Because the project is evolving, ratings remain provisional.

4.1.4. Barcelona

Barcelona offers a different example of a citizen-focused SC model. The city's focus on open data, digital rights, public sector leadership, and civic platforms has been extensively analyzed as a more participatory model of smart urbanism [32]. However, this case demonstrates that participatory models of SCs continue to experience significant barriers surrounding funding, scaling, interoperability, and institutional coordination.

Uniform framework application: technological–infrastructural limitations are primary, and the other five categories are secondary. Public value and data sovereignty commitments improve legitimacy, but delivery across legacy systems and institutions creates coordination, funding, interoperability, and scaling costs [32,58,61]. For SRE, municipal digital principles must be translated into procurement requirements, building interfaces, asset-owner responsibilities, and viable retrofit pathways.

4.2. Case-Based Limitation Coding

To avoid treating all limitations equally, each case was coded according to whether a limitation was primary or secondary. A primary limitation refers to a clearly documented and central challenge in the case. A secondary limitation refers to a relevant but less dominant issue.

Taking conceptual and strategic limitations as an example for the calculation, these limitations are primary in Toronto, Songdo, and NEOM ($P = 3$) and secondary in Barcelona ($S = 1$); weighted prevalence is therefore $(2 \times 3) + 1 = 7$ of 8. The same calculation is applied to every category. This prevalence score does not determine the severity score.

Table 4 reveals that the Toronto project focused mainly on governance, privacy, and public trust; Songdo featured technology-centered and less socially integrated development; NEOM raised governance, ethical, and environmental concerns; and Barcelona faced a primary technological–infrastructural limitation alongside secondary funding, scaling, institutional coordination, digital inclusion, and participation challenges.

Table 4. Smart city and smart real estate limitations. P = primary; S = secondary; P/4 and S/4 report the number of case designations; weighted prevalence equals $W = (2 \times P) + S$, maximum 8. The complete case-category evidence ledger is provided in Supplementary Table S3. Author, 2026.

Limitation Category	Toronto/ Sidewalk Labs	Songdo	NEOM	Barcelona	P/4	S/4	Weighted Prevalence
Conceptual and strategic	P—public/ private mandate	P—technology-first model	P—techno-utopian scale	S—rhetoric/ delivery gap	3/4	1/4	7/8
Technological and infrastructural	S—data infrastructure	P—integration/ social fit	S—unproven systems	P—legacy integration/ scale	2/4	2/4	6/8
Governance and institutional	P—data authority/ firm scope	S—top-down planning	P—centralization/ transparency	S—coordination	2/4	2/4	6/8
Economic and financial	S—redesign/ feasibility	P—cost and uptake	P—capital and demand risk	S—funding/scale	2/4	2/4	6/8
Social and ethical	P—privacy/ trust	P—social integration	P—rights/ displacement	S—inclusion/ participation	3/4	1/4	7/8
Environmental	S—unverified life cycle claim	S—eco-city claim	P—embodied/ ecological risk	S—implementation gap	1/4	3/4	5/8

Conceptual–strategic and social–ethical limitations each have a weighted prevalence of 7/8; technological–infrastructural, governance–institutional, and economic–financial limitations each have a weighted prevalence of 6/8; and environmental limitations have a weighted prevalence of 5/8. These are transparent case pattern summaries, not prevalence estimates across the entire SC literature.

4.3. Cross-Case Comparison

As summarized in Table 5, several themes emerge from the four cases. First, developing a social contract between the public and the government is critical to building public trust. The lack of robust data governance and clear accountability in Toronto undermined public confidence in the project. Second, despite its advanced technology, Songdo demonstrates that smart infrastructure alone will not support the use of these systems without social and cultural planning focused on the people they serve. Third, the governance model can affect the risks associated with delivering these programs and projects. Although centralized governance models, such as NEOM, can accelerate project implementation, they may also raise ethical and legitimacy concerns. Lastly, participatory governance in Barcelona has increased the project’s legitimacy; however, implementation, financing, and integration challenges persist.

Table 5. Cross-case comparison of governance/development models, dominant causal mechanisms, observed patterns, and smart real estate implications. Author, 2026.

Case	Governance/ Development Model	Dominant Mechanism	Observed Pattern	SRE Implication
Toronto/ Sidewalk Labs	Corporate-led public–private district	Authority and data rights lagged behind platform and development ambition	High legitimacy conflict; cancellation before operation	Treat data governance, public–realm interfaces, and exit rights as development prerequisites.
Songdo	State-enabled, technology- and property-led greenfield city	Delivery capacity outpaced social learning and demand adaptation	Technical completion with weaker social fit and uptake	Value depends on adaptability, occupancy, placemaking, and life cycle operation—not specification alone.
NEOM	Centralized state-capitalist megaproject	Exceptional scale and concentrated authority reduce the need for external correction of assumptions.	Feasibility, rights, environmental, and long-horizon risks cluster	Stage-gate investment, independent assurance, affected-community safeguards, and whole-life testing are essential.
Barcelona	Municipal, citizen-oriented existing city transformation	Public value alignment improves legitimacy but diffuses delivery across legacy institutions	Lower legitimacy risk; persistent coordination, funding, and scaling constraints	Translate public digital principles into interoperable building interfaces and retrofit finance.

Finally, SRE can be viewed as an extension of overall SC development, as smart buildings, smart districts, and SRE assets will achieve their overarching urban objectives through integrated, coordinated relationships with citywide infrastructure, governance, and sustainability. Without such integration, SRE risks becoming fragmented, costly, and concentrated in a limited number of high-value properties because cross-system synergies are not realized.

Across the cases, four mechanisms explain why patterns of limitation differ. Allocation of authority shapes legitimate control of data, land, interfaces, and service standards; feedback capacity determines whether participation, pilots, and operational evidence correct assumptions; incentive alignment determines who bears costs and captures benefits; and institutional integration determines whether responsibilities work across departments,

utilities, buildings, and life cycle phases. Toronto's binding problem was authorization before operation, Songdo's was adaptation after delivery, NEOM's is concentrated on long-horizon risk, and Barcelona's is coordination across plural legacy institutions.

4.4. Severity and Scope of Limitations

The severity and scope assessment assigns high severity to social and ethical, governance and institutional, and technological and infrastructural limitations, and medium–high severity to conceptual and strategic limitations. The analysis does not calculate a composite highest overall impact. These limitations can affect execution success, public legitimacy, trust, and long-term efficiency. Although economic and environmental limitations are also significant, their category-level severity is rated moderate because their consequences are more context- and life cycle-dependent and can often be mitigated through established financial, procurement, and assessment measures.

Table 6 applies—not redefines—the formal criteria in Section 3.5. The stated mechanism and consequence support each severity rating; $P/4$, $S/4$, and $(2 \times P) + S$ make the case prevalence calculation reproducible within this four-case design. Severity is reported independently and is not inferred from the weighted prevalence value.

Table 6. Severity, scope, and case prevalence assessment of limitation categories. Severity is judged independently from weighted prevalence. Author, 2026.

Category	Case Pattern	P/4	S/4	Weighted/8	Severity (Basis)	Scope (Basis)	Bubble Position
Conceptual and Strategic	P–P–P–S	3/4	1/4	7/8	2.5—material and cross-scalar; serious but not uniformly system-wide or long-duration	2—affects city goals and asset criteria	Both/Medium–High
Technological and Infrastructural	S–P–S–P	2/4	2/4	6/8	3—can interrupt core services, integration, security, and adaptation	2—city and building systems are interdependent	Both/High
Governance and Institutional	P–S–P–S	2/4	2/4	6/8	3—can compromise authority, rights, legitimacy, accountability, and delivery	1—city/public-system dominant, with cross-scalar consequences	SC/High
Economic and Financial	S–P–P–S	2/4	2/4	6/8	2—material to viability and access but usually mitigable	2—affects both city finance and asset economics	Both/Medium
Social and Ethical	P–P–P–S	3/4	1/4	7/8	3—rights, trust, inclusion, legitimacy, and adoption are materially affected	2—affects citizens, occupants, and users	Both/High
Environmental	S–S–P–S	1/4	3/4	5/8	2—material and potentially irreversible, but evidence varies by project stage	3—life cycle impacts concentrate in developments and assets	SRE/Medium

Legend: P = primary limitation; S = secondary limitation.

Figure 3 represents the severity and scope of the limitations of both SCs and SRE, based on the literature and cross-case analysis. The placement of each bubble is based on the severity and scope assessment in Table 6. In contrast, bubble size represents weighted prevalence across cases, with primary manifestations weighted by 2 and secondary manifestations weighted by 1.

It visualizes the assessment shown in Table 6. Conceptual and strategic limitations exist at the interface between the SC and the SRE. This is because limitations in conceptual definitions, deficiencies in performance indicators, “smart-washing”, and the blurring of the distinction between smartness and sustainability pose challenges for both levels of approach. The limitations associated with governance and institutions are located between the SC and cross-scalar levels because these limitations relate specifically to decision-making at the city level; however, such limitations also influence real estate development, the governance of data, and public–private partnerships, in addition to influencing SC development itself and the potential of the city and its future.

On the other hand, when it comes to the limitations posed by infrastructure and technology, the limitations span across both levels, as interoperability, cybersecurity, and systems integration pose issues across both urban platforms and building systems. The limitations posed by social and ethical issues were considered severe, since they have an immediate impact on users’ trust in the system, willingness to participate, willingness to share personal data, and perceptions of legitimacy. Economic and environmental limitations were rated moderate at the category level because their consequences are more context- and life cycle-dependent and are often mitigable through financial, procurement, and assessment measures, which will generally appear over longer timeframes than those of technology or social issues.

In conclusion, the outcomes of this study suggest that achieving successful smart development will require more than the adoption of technology; it will necessitate clear conceptual foundations, integrated governance, ethical use of data, financial viability, public participation, environmental accountability, and strong coordination between city- and real estate-level implementation systems.

5. Discussion

5.1. Theoretical Interpretation: Smartness as Governed Sociotechnical Capacity

The findings refine existing multidimensional frameworks. Technology–people–institution and integrative-factor models correctly anticipate that technological systems are embedded in governance, community, economy, and environment [40,41]. The cross-case evidence provides a mechanistic interpretation: institutional arrangements determine whether inputs are transformed into legitimate, adaptive, and lasting outcomes. This supports governance scholarship that treats smart city transformation as an organizational and political process [28–30,33–39,49] while challenging technology-supply accounts that assume more infrastructure automatically produces greater smartness.

The results indicate that the limitations of SCs and SREs are interrelated governance, implementation, economic, ethical, social, and environmental challenges rather than merely technical barriers. This has significant consequences for how smartness is defined, regulated, financed, evaluated, and translated into public and real estate value. Smart technology is expected to increase efficiency, improve service delivery and resource management, and enhance real estate performance. However, its effectiveness depends on how projects are defined, planned, governed, funded, implemented, and accepted by users. Smartness should therefore be considered a multidimensional process rather than a purely technological state [3,4].

Smartness has already been defined and measured through standards, indicator sets, assessment tools, and city indices [42–44]. A key issue is therefore not the absence of definitions or measures, but inconsistency in how definitions, indicators, and evaluation criteria are selected, weighted, locally adapted, and applied across projects. When smartness is poorly defined, a project may achieve technological visibility, branding, and investor attention without producing measurable public value, sustainability, social inclusion, or lasting asset performance. This creates a risk of “smart-washing”: using smart labels to present cities, districts, or real estate developments as innovative without demonstrating the governance, environmental, social, or operational benefits that should accompany those claims. These concerns are consistent with the critical smart city literature, which argues that smartness can function as entrepreneurial urban branding and corporate narrative rather than evidence of measurable public value [10,13,14,27]. Smart initiatives should therefore establish clear objectives, measurable indicators, and defined boundaries before implementation, covering technological performance, sustainability, social value, and real estate life cycle performance.

Critical smart urbanism scholarship explains whose purposes, narratives, and ownership structures are embedded in smartness [4,5,10,12,14,22,25–27]. Sociotechnical and institutional capacity perspectives explain how misalignment becomes implementation failure. The six-category diagnostic integrates these views by requiring each coded limitation to specify both a mechanism and a consequence. It extends recent adverse-effect taxonomies [46,49] by adding city–real estate scope, transparent case prevalence, governance model comparison, and an explicit path from diagnosis to accountable mitigation.

5.2. Why Governance Models Produce Different Limitation Patterns

Governance was identified as a key limitation in the comparative case studies. The Toronto Sidewalk Labs case showed how ambiguities in data ownership, public–private roles, and accountability can undermine the legitimacy of smart city initiatives [45,54]. Municipalities should establish transparent governance arrangements before deployment, including clear data rights, procurement rules, privacy responsibilities, public–benefit requirements, and limits on private-sector control. Public–private partnerships should be structured around long-term public value, transparent accountability, and safeguards against excessive private sector control.

The findings confirmed the significance of public involvement. The experiences of Songdo and NEOM reflect the risks of technology-driven, top-down planning, in which advanced smart technologies can be at odds with social acceptance, local communities, and human-centered design [50,57]. In contrast, Barcelona suggests that participatory governance, open data, and digital rights can strengthen legitimacy and support service delivery, although there are challenges around financing, scaling, and coordination [32,58].

The four mechanisms identified in Section 4.3 connect observed limitations to mitigation. Clear authority and data rights address Toronto’s authorization gap; participatory feedback and post-occupancy learning address Songdo’s adaptation gap; independent stage gates, rights safeguards, and whole-life assurance address NEOM’s concentration of assumptions and risk; and cross-department decision rights, interoperable standards, and retrofit finance address Barcelona’s coordination burden. The cases therefore test and refine theory by showing which institutional function fails under each development model, rather than merely demonstrating that governance matters.

5.3. Cross-Scalar Implications for Smart Real Estate

Integration is also a key challenge for SRE development. Smart buildings and districts contribute to citywide goals only when they are connected to urban energy grids, mobility

networks, data platforms, and governance structures. When developed independently, SRE may become fragmented, expensive, and limited to high-value developments. Coordination is therefore required among developers, municipalities, and technology providers throughout the real estate life cycle [7,9].

It is also necessary to consider the financial viability of implementing the technology. Barriers to adoption may include the capital-intensive nature of implementation, uncertainty about the return on investment, vendor lock-in, and the need for continuous maintenance and technical support. Phased implementation, modular systems, open standards, public financing incentives, and cost–benefit assessment can help overcome these challenges. When evaluating SRE products and services, one should look beyond the initial market value. Operational savings, user satisfaction, adaptability, evaluation of sustainability performance, and long-term asset resiliency should also be considered [9,21].

For real estate actors, the city–asset boundary is a governance interface. Data rights become leases, consent, and platform access provisions; interoperability becomes an interface and a procurement requirement; inclusion becomes accessibility and affordability; and environmental credibility becomes embodied carbon, energy, water, maintenance, and end-of-life performance. Appraisal should therefore include total cost of ownership, upgrade and exit options, cybersecurity and privacy liabilities, user adoption, interoperability, resilience, distributional effects, and verified life cycle performance—not only expected energy savings or a rent premium [7,9,15,18,21].

5.4. Policy, Practice, and Investment Recommendations

Concerns about privacy and surveillance should not be considered secondary risks. It is well-established that data collection is a key part of any SC or SRE operation; however, if residents, occupants, and users do not understand how their personal data is collected, stored, used, shared, and monetized, this can erode community trust in technology. Therefore, when designing and developing city-level platforms and building-specific systems, data privacy principles should be adhered to by embedding privacy-by-design, minimizing data collection, providing transparent mechanisms for obtaining consent, ensuring clear ownership of collected data, and incorporating independent oversight into the technology's operations [22,23].

Although numerous smart technologies have been developed to support sustainability initiatives, there are still potential drawbacks, such as increased energy use, electronic waste, and greenwashing, if they are not examined throughout their entire life cycles [16,17]. Therefore, smart cities and smart real estate initiatives should implement life cycle assessment, circular procurement, renewable energy use, and measurable sustainability indicators.

A recommendation is useful only when it identifies the responsible actor, the implementation sequence, the supporting evidence, and the value to be tested. Standards and policy guidance offer practical starting points for outcome indicators, data governance, people-centered design, interoperability, and AI oversight [35,36,39,42–44,47,48,59–64]. Before adoption, each measure should have a local baseline, a named owner, a timeline, an audit method, a distributional assessment, and a life cycle cost–benefit or value-for-money test.

Table 7 is presented as one continuous decision matrix so that the analytical basis and implementation response remain visible in the same row. It links each limitation to its category, level, case basis, evidence/theoretical basis, severity, weighted prevalence, performance impact, recommended measure, implementation strategy, responsible actors, and expected financial and non-financial return. The returns are hypotheses to be tested, not guaranteed benefits, and costs and benefits should be reported separately when they accrue to different stakeholders.

Table 7. Integrated recommendations framework for addressing smart city and smart real estate limitations. Author, 2026.

Cat	Limitation	Level	Severity	WP.	Impact on Performance	Recommended Measure	Implementation Strategy	Responsible Actors	Expected Financial/ Non-Financial Return	Evidence/ Theoretical Basis
Conceptual and Strategic	Lack of a unified definition of smartness	Both	2.5 (M-H)	7/8	Creates inconsistent implementation, weak evaluation, and fragmented objectives	Develop standardized but adaptable smartness frameworks and key performance indicators	Adopt recognized indicators while adapting them to local contexts	Municipalities define local goals; national governments develop standards; researchers support frameworks; developers align projects with indicators	Comparable outcomes; lower misallocation and rework risk; stronger benefit realization.	Multidimensional and assessment frameworks [6,40–44]
	Confusion between smartness and sustainability	Both	2.5 (M-H)	7/8	Leads to greenwashing and unrealistic sustainability claims	Separate smart performance from sustainability performance	Use separate digital, social, and environmental assessment indicators	Municipalities require sustainability reporting; developers apply life cycle assessments	Credible claims; lower transition/reputation risk; verified carbon, energy, water, and life cycle value.	Smart–sustainable distinction and life cycle research [16,17,52,53]
	Technology-driven planning without social objectives	SC	2.5 (M-H)	7/8	Projects become infrastructure-centered rather than people-centered	Adopt human-centered and participatory planning models	Include citizens and users during planning and implementation	Municipalities lead participation; citizens provide input; developers integrate community needs	Higher adoption and service fit; fewer unused features; greater option value.	People/institution and people-centered frameworks [12,39–41,47]
Technological and Infrastructure	Interoperability gaps	Both	3 (H)	6/8	Weak integration between city systems and building-level systems	Use open standards and interoperable platforms	Require open APIs, data compatibility, and modular technologies	Municipalities set procurement rules; technology providers build interoperable systems; developers avoid closed platforms	Lower integration, migration, and switching costs; longer useful life and less downtime.	Large-system coordination and interoperability evidence [29,48,61,63]
	Cybersecurity vulnerabilities	Both	3 (H)	6/8	Risk of data breaches, infrastructure disruption, and public distrust	Apply cybersecurity-by-design	Conduct regular audits, risk assessments, and incident-response planning	Technology providers secure platforms; municipal IT teams monitor systems; building operators protect asset-level data	Avoided breach/outage losses, lower compliance exposure, and greater trust.	Ethics, data governance, and risk-based oversight [23,35,36,62,64]
	Legacy infrastructure incompatibility	SC	3 (H)	6/8	Limits the integration of new smart systems	Apply phased modernization strategies	Integrate smart systems gradually into existing infrastructure	Municipalities plan upgrades; utilities coordinate infrastructure; technology firms provide compatible systems	Lower retrofit disruption and integration cost; faster service improvement.	Building life cycle and city implementation [18,21,48,61]
	Technological obsolescence	SRE	3 (H)	6/8	Rapid aging of smart systems increases operational and replacement costs	Use modular and upgradeable technologies	Develop long-term replacement and maintenance plans	Developers select adaptable systems; facility managers maintain systems; investors fund upgrades	Reduced stranded assets and capex volatility; higher flexibility and residual value.	SRE life cycle and modularity evidence [7–9,18,21,48]

Table 7. Cont.

Cat	Limitation	Level	Severity	WP.	Impact on Performance	Recommended Measure	Implementation Strategy	Responsible Actors	Expected Financial/Non-Financial Return	Evidence/Theoretical Basis
Governance and Institutional	Fragmented governance structures	SC	3 (H)	6/8	Weak coordination between agencies and stakeholders	Establish integrated governance frameworks	Create SC coordination bodies linking departments and stakeholders	Municipalities lead coordination; public agencies share data; developers and utilities align with city systems	Shorter decision cycles, fewer duplications, and stronger delivery accountability.	Smart governance and coordination research [28,29,33,34,38,48]
	Weak data governance	Both	3 (H)	6/8	Creates uncertainty around ownership and use of urban and building data	Develop transparent data governance policies	Define ownership, consent, storage, sharing, and accountability	Municipalities regulate urban data; developers/building owners manage asset data; users retain data rights	Lower dispute/compliance risk; lawful reuse, trust, and clearer service value.	Data accountability and Toronto evidence [35,36,45,49,58,62]
	Corporate over-reach/vendor dependency	Both	3 (H)	6/8	Public interest may become secondary to private interests	Strengthen public oversight and procurement regulation	Use transparent contracts, exit clauses, and vendor-neutral systems	Municipalities control procurement; regulators review contracts; technology firms comply with public interest rules	Preserved public control and bargaining power; lower exit and concentration risk.	Critical platform and Toronto research [14,26,27,45,54]
	Weak regulatory frameworks	SC	3 (H)	6/8	Delays implementation and creates legal uncertainty	Develop adaptive SC regulations	Introduce digital governance, AI, and data-use policies	National governments set legal frameworks; municipalities implement local rules; regulators monitor compliance	Lower legal uncertainty and delay; greater compliance and investment confidence.	Data, digital, interoperability, and AI governance [35,38,62–64]
Economic and Financial	High implementation costs	Both	2 (M)	6/8	Limits adoption, scalability, and equitable access	Use phased implementation and blended financing models	Combine public funding, PPPs, private investment, incentives, and grants	Municipalities provide incentives; developers invest strategically; financial institutions support green/smart financing	Lower sunk-cost exposure and improved capital efficiency through stage-gated investment.	SRE life cycle and case-feasibility evidence [8,9,15,21, 31,51,59,60]
	Uncertain ROI	SRE	2 (M)	6/8	Reduces investor confidence and slows adoption	Conduct life cycle cost–benefit analysis	Evaluate operational savings, asset value, user satisfaction, and sustainability gains.	Developers/investors assess long-term value; facility managers provide performance data; researchers develop valuation models	Stronger investment confidence and whole-life value through transparent NPV, TCO, and sensitivity testing.	City real estate evaluation and life cycle value [7–9,15,18,21]
	Vendor lock-in	Both	2 (M)	6/8	Reduces flexibility and increases long-term costs	Promote open-source and interoperable systems	Require flexible procurement standards and exit clauses	Municipalities require vendor-neutral procurement; developers avoid closed systems; technology providers support portability	Lower switching/refinancing costs and improved flexibility and residual value.	Data governance, procurement, and interoperability [36,48,62,63]
	Unequal access to smart infrastructure	SC	2 (M)	6/8	Deepens urban inequality and digital exclusion	Prioritize inclusive infrastructure investment	Expand smart services into underserved communities	Municipalities target disadvantaged areas; national governments fund inclusion; community groups identify local needs	Broader service uptake, fairer value distribution, and improved social outcomes.	Participation and people-centered governance [12,39,47,58]

Table 7. Cont.

Cat	Limitation	Level	Severity	WP	Impact on Performance	Recommended Measure	Implementation Strategy	Responsible Actors	Expected Financial/Non-Financial Return	Evidence/Theoretical Basis
Social and Ethical	Privacy concerns	Both	3 (H)	7/8	Reduces public trust and acceptance	Apply privacy-by-design principles	Minimize data collection and provide transparent consent mechanisms	Technology providers design safeguards; municipalities enforce rules; building operators protect occupant data	Reduced rights and reputation risk; higher trust and adoption.	Ethics, accountability, Toronto evidence [22,23,35,45,49,54,62]
	Surveillance and mass data collection	SC	3 (H)	7/8	Raises ethical and civil rights concerns	Limit unnecessary monitoring	Establish independent oversight and auditing systems	Municipalities regulate surveillance; civil society monitors rights; technology firms limit data extraction	Lower civil rights and legitimacy risks; stronger accountability.	Critical smart urbanism and data governance research [22,23,35,45,54]
	Digital divide	Both	3 (H)	7/8	Excludes vulnerable groups from smart services	Improve digital accessibility and literacy	Expand affordable internet access, training, and accessible platforms	Governments fund access; NGOs/community groups provide training; technology firms design inclusive tools	Broader access and service uptake; reduced exclusion and service disparity.	Participation and people-centered governance [12,38,39,58]
	Weak public participation	SC	3 (H)	7/8	Reduce legitimacy and long-term public support	Adopt participatory governance models	Use co-design workshops, digital platforms, and participatory budgeting	Municipalities organize participation; citizens provide input; developers integrate community feedback	Better service fit, legitimacy, and social license; fewer contested redesigns.	Participation, legitimacy, and Barcelona evidence [12,38,39,49,58]
	Algorithmic bias and exclusion	Both	3 (H)	7/8	May reinforce social inequality and discrimination	Increase transparency in AI systems	Conduct ethical audits and fairness testing	Technology providers audit algorithms; regulators define standards; researchers evaluate bias	Lower discrimination/compliance risk and more equitable outcomes.	Ethics, adverse-effect, and AI oversight research [23,35,46,47,64]
Environmental	High ICT energy consumption	Both	2 (M)	5/8	Smart systems may increase energy demand	Integrate smart systems with renewable energy	Use smart grids, efficient data systems, and low-energy technologies	Municipalities regulate energy performance; developers install efficient systems; energy providers support renewable integration	Lower operating costs, energy price exposure, and carbon liability.	Smart-sustainable distinction and ecological critique [16,17,52,53]
	Electronic waste (e-waste)	SRE	2 (M)	5/8	Short technology life cycles increase waste generation	Promote circular economy strategies	Use recyclable hardware, longer warranties, and reuse strategies	Developers/building owners procure responsibly; technology providers offer repairable systems; waste authorities manage recycling	Longer component life, recovered material value, and avoided replacement capex.	Building life cycle, modularity, and ecological critique [18,21,52]
	Greenwashing	Both	2 (M)	5/8	Misleading sustainability claims weaken accountability	Require measurable sustainability indicators	Apply third-party sustainability verification	Certification bodies verify claims; municipalities require reporting; developers disclose performance data	Lower reputation and enforcement risk; greater credibility for access to sustainable finance.	Assessment critique, sustainability, smart-washing [16,17,27,43,44,52,53]
	Weak life cycle sustainability assessment	SRE	2 (M)	5/8	Sustainability performance is not measured holistically	Apply full life cycle assessment methods	Evaluate the environmental impact from development to demolition	Developers conduct assessments; certification bodies verify performance; municipalities require reporting	Verified whole-life performance, lower life cycle risk, and better capital planning.	Life cycle and smart-sustainable assessment research [16–18,21,52,53]

Note: WP = weighted case prevalence, calculated at category level as $(2 \times P) + S$; P = primary case manifestation; S = secondary case manifestation; M = moderate; M-H = medium-high; H = high. More details are provided in Supplementary Table S5.

Based on the identified categories of limitations and cross-case findings, Table 7 presents an integrated framework of recommendations for addressing limitations in SCs and SRE. The table combines analytical and practical dimensions by linking each limitation to its affected level, severity, weighted prevalence, impact on performance, recommended measure, implementation strategy, responsible actors, expected financial and non-financial return, and evidence and theoretical basis. More details are provided in Table S5.

No single actor can address these limitations alone. Municipalities control governance, procurement, accountability, and access to public infrastructure. Developers and owners translate city goals into life cycle decisions for sites, buildings, and portfolios. Technology providers are responsible for interoperability, security, privacy, portability, and upgrade paths. National authorities set legal and funding conditions, while citizens, civil society organizations, certification bodies, and researchers help shape, monitor, and verify outcomes.

Overall, the discussion shows that smart cities and smart real estate must be implemented in a coordinated manner. Interoperability requires municipal procurement rules, cooperation among technology providers, and developer compliance. Data privacy requires an appropriate legal framework, ethical standards, transparent management, and clear information for users. Sustainability likewise requires measurable indicators, third-party verification, and life cycle assessment. Progress in smart development therefore depends on cooperation across the public and private sectors, technology providers, civic institutions, and academia.

5.5. Limitations and Future Research

Five limitations constrain the study. First, it should be acknowledged that the study is a focused critical review rather than an exhaustive systematic review. Second, all evidence is secondary, and source availability and critical scrutiny differ across cases. Third, the cases are deliberately heterogeneous in maturity, political economy, governance, and scale; they support mechanism comparison but not direct ranking or statistical generalization. Fourth, coding and ratings were not independently double-coded. Fifth, severity and scope are ordinal analytical judgments, and NEOM remains an evolving project. Explicit rules, triangulation, negative-case searching, and conservative wording improve auditability but do not remove these limitations.

6. Conclusions

This study examined barriers to smart city and smart real estate development through a focused review and a comparison of Toronto, Songdo, NEOM, and Barcelona. Across the four cases, technology was only one part of the explanation. Governance, finance, ethics, environmental performance, social acceptance, and long-term operation determined whether technical ambition produced lasting value.

The research identified six major types of limitations to achieving smartness: conceptual and strategic; technological and infrastructural; governance and institutional; economic and financial; social and ethical; and environmental. Several limitations hinder the realization of the potential of smart cities and smart real estate, including insufficient governance, a lack of a clear definition of smartness, privacy and surveillance challenges, limited interoperability, high implementation costs for smart technologies, and the false assumption that being smart means being sustainable. Some limitations can manifest at both levels and therefore require integrated planning and coordination.

In response to the research question, the case findings show that limitations become binding through misalignment among technology, authority, incentives, social legitimacy, and life cycle conditions. Technology alone does not guarantee smart development: Toronto

was constrained by authority, data rights, and trust; Songdo by social fit, adaptability, and uptake; NEOM by concentrated feasibility, rights, and life cycle risks; and Barcelona by coordination, legacy integration, financing, and scale.

Conceptual ambiguity can also facilitate smart-washing. Cities, buildings, or projects may receive the “smart” label without delivering social, environmental, or operational value. Clear definitions, objective indicators, transparent governance, and independent evaluation are therefore needed. Smart real estate should be considered throughout the development and operational life cycle, and smart city performance should be evaluated according to public and environmental value rather than technology adoption alone.

The theoretical contribution of this study is to explain the relationship between city-level institutions and real estate decisions. The proposed framework distinguishes limitation category from severity, scope, prevalence, mechanism, and consequence, and uses critical urbanism, sociotechnical theory, and institutional capacity to interpret differences among the cases. Its contribution is therefore explanatory: it shows why different development models create different constraints and how those constraints reach the real estate life cycle.

The practical contribution is to show that governance, participation, interoperability, rights protection, and life cycle assurance should be established before procurement and capital lock-in. Municipalities should publish outcome baselines and clarify data authority; developers and owners should test whole-life value and property adaptability; technology providers should ensure security, portability, and auditability; regulators should enforce rights and truthful claims; and affected communities should have demonstrable influence. These recommendations remain subject to the limitations of secondary data, heterogeneous cases, single-coder analysis, and ordinal ratings.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/smartcities9090144/s1>, Table S1, review protocol and source-selection logic; Table S2, coding and rating rules; Table S3, complete case-category evidence ledger; Table S4, severity and weighted prevalence calculation audit; Table S5, expanded evidence, implementation, return, and verification records supporting Table 7; Table S6, complete numbered inventory of the 64 cited sources. An Excel version of Tables S1–S6 is also provided to permit direct inspection of the formulas and coding ledger.

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Abbreviations

The following abbreviations are used in this manuscript:

Abbreviation	Meaning
AI	Artificial intelligence
ICT	Information and communication technology
LCA	Life cycle assessment
NPV	Net present value
P	Primary case manifestation
PPP	Public–private partnership
ROI	Return on investment
S	Secondary case manifestation
SC	Smart city
SRE	Smart real estate
TCO	Total cost of ownership

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