A Comprehensive Evaluation Framework for Smarter Cities and Real Estate

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1 ABSTRACT

The terms smart city and smart real estate are often used with different definitions and scopes, as several fields and experts are involved in developing them, and each expert defines them based on their field. This study traces the concept of smart cities and identifies what a smart city and smart real estate are. There is a need for a framework that identifies what makes a city or real estate "smart" and aligns the definition to be suitable across different fields. Integrating smart technologies in urban development is crucial for enhancing cities' and real estate projects' smartness, efficiency, and sustainability. Although real estate technology-based companies have grown significantly, the global real estate industry still lags several years behind the technology curve. This study introduces a comprehensive evaluation framework to assess the smartness and integration of cities and real estate. The study identifies key success features and indicators. The developed framework is based on seven identified categories: smart governance, smart people, smart infrastructure, smart energy, smart environment, smart technology, and real estate status. A comparative benchmark analysis was utilized to demonstrate the practical application of the framework and to assess the current stages of smartness worldwide, revealing significant integration of smart solutions and highlighting improvement areas. The findings highlight the correlation between indicators and the strategies for integrating smart real estate into smart cities. The developed framework provides valuable insights for urban planners, municipalities, real estate developers, and other stakeholders to achieve smarter development and improve urban living conditions.

Keywords: smart city, smart buildings, smart real estate, smart technologies, evaluation framework

2 INTRODUCTION

Smart cities (SCs) and smart real estate (SRE) are rapidly becoming focal points of interest for countries worldwide. SCs leverage advanced Information and Communication Technology (ICT) infrastructure to enhance urban development, public services, and citizen engagement, promoting sustainability, productivity, transparency, and efficiency (Samarakkody & Kulatunga, 2019). The efficiency of SCs heavily depends on SRE and smart buildings; Smart buildings build SCs (Al-Rimawi & Nadler, 2023). By 2026, the global SB market will grow to 121.6 billion USD, with a compound annual growth rate of 10.9% (MarketsandMarkets, n.d.). The revenues and growth of the German SC market 2017 – 2022 had an increase of 16.5%, with building automation having the highest share of 21.1% of the market (Arthur D. Little GmbH & eco, 2022). The integration of SC and SRE is crucial for creating a connected, efficient, and sustainable urban environment, addressing global environmental and socioeconomic challenges. Countries like Japan and China are investing heavily in SC and SRE initiatives to rebuild and transform urban areas, aiming to improve the quality of life and promote sustainable urbanization (Schipper & Silvius, 2018; Washburn & Sindhu, 2010). The synergistic integration of SC and SRE is essential for achieving these goals.

3 BACKGROUND

3.1 Smart City Definition and Concept

The origin of the term SC can be traced back to the 1990s, as many related concepts appeared within that period. This evolved from the concept of a knowledge-based city in 1990, which emphasized the shift towards knowledge-driven urban development. In 1991, the term global city emerged, linking cities to global socio-economic impacts. By 1993, the term ubiquitous city was introduced, highlighting digital networks in the urban environment (Šiurytė, 2015). The late 1990s saw the rise of smart growth, emphasizing technology-driven urban development. In 2006, two key concepts emerged: the Intelligent city, focusing on

high learning and innovation capacities, and MESH city (Mobile, Efficient, Subtle, Heuristics), associating ICT with modern urban infrastructure (Samarakkody & Kulatunga, 2019; Schipper & Silvius, 2018).

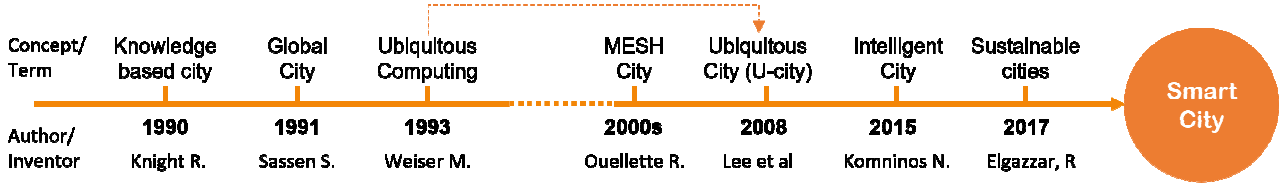

Fig. 1: Smart City Concept Evolvments, Author, 2025.

The definition of SC has been used in different ways, and it is defined based on different fields. However, researchers have not agreed upon what SC is based on in their field. Washburn and Sindhu are used, as they define SC as the use of smart computing technologies to make the critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, transportation, and utilities – more intelligent, interconnected, and efficient (Washburn & Sindhu, 2010).

3.1.1 Smart City Components

In comparison between SC and a traditional city, SC integrates Information and Communication Technology (ICT) infrastructure with its various components, these components work together to ensure urban development, efficient public services, and enhanced citizen engagement, making the city more sustainable, productive, transparent, effective, and efficient. In contrast, a basic city relies on conventional methods and infrastructure with minimal tech integration, often resulting in less efficiency and sustainability (Samarakkody & Kulatunga, 2019). Based on the review of various sources, Figure 2 identified SC components, seven components are interrelated with SC and SRE: smart governance, smart people, smart environment, smart infrastructure, smart energy, smart technology, and smart buildings. These components, linked by SC technologies, are critical for developing the evaluation framework. Smart governance includes public participation, data transparency, internet of things (IoT) devices for quality of life, and health and safety measures through e-health and telecare. Smart energy integrates sustainable sources, efficient distribution with smart infrastructure, grids, meters, and information infrastructure collecting and sharing energy data. Smart technology links all components with state-of-the-art technologies. Smart environment includes pollution control, water quality monitoring, and waste management with sensors, policies, and strategies. Smart buildings, equipped with IoT sensors, enhance user satisfaction. Smart infrastructure, fundamental to SCs, includes communication infrastructure. The smart transportation system shifts to Mobility-as-a-Service, connecting users through IoT infrastructure (Al-Rimawi & Nadler, 2023).

Fig. 2: Smart City Concept Evolvments, Author, 2025.

3.2 Smart Real Estate

SRE refers to the integration of advanced and disruptive technologies into the real estate sector to enhance the functionality, efficiency, sustainability, and user experience of buildings and properties. This includes the use of smart technologies such as big data, artificial intelligence (AI), ICT, IoT, clouds, drones, 3D scanning, wearable technologies, virtual reality and augmented reality (VR and AR), geographic information systems (GIS), building information modeling (BIM), digital twin, blockchain and smart contracts. Smart real estate aims to optimize energy consumption, improve security, enhance comfort, and provide real-time data for better decision-making. It encompasses smart buildings, smart homes, and smart cities, all working together to create a more connected, efficient, and sustainable urban environment (Al-Rimawi & Nadler, 2025).

SRE involves the broader application of advanced technologies across the entire real estate ecosystem, including residential, commercial, and industrial properties. In contrast, smart buildings concentrate on applying technology within individual structures to enhance their internal systems and operations, leveraging sensors, software, and networked devices to monitor and control aspects like energy usage, lighting, heating, ventilation, and security. While SRE aims to provide a sustainable, innovative, and user-centered environment for consumers, smart buildings focus on optimizing performance, comfort, and sustainability within the building itself. Thus, SRE covers the entire ecosystem, whereas smart buildings emphasize automation and monitoring within individual structures. While traditional buildings lack the technological integration of smart buildings and SRE. Traditional buildings rely on manual controls for heating, lighting, and security, and don't use real-time data or automation. This results in less optimized energy consumption, higher utility costs, and a larger environmental footprint, with lower levels of user experience and comfort.

3.2.1 Real Estate Integration into Smart Cities

The level of real estate (RE) integration into smart cities (SC) depends on the SC network's capabilities and the resources provided by the RE developer. Various RE developments in SC strategies exist, each differing in smartness and intelligence levels. All strategies should be part of a coherent plan to ensure effective integration into SC (Al-Rimawi & Nadler, 2023). Three integration strategies are identified:

(1) Leading Strategy: RE development becomes the dominant factor in smartness, influencing its surroundings and setting new standards for others to follow, (2) Following Strategy: Developments use, dominant and leading benchmarks, potentially located elsewhere; (3) Waiting Strategy: Developments incorporate fragmented features of intelligence and smartness.

4 MATERIALS AND METHODS

4.1 Evaluation framework development

4.1.1 Smart Evaluation Framework Purpose

The evaluation framework aims to identify success indicators for SCs and SRE. It assesses performance, identifies deficiencies, and highlights potential improvements. The framework reveals interoperability capabilities between SCs and SRE, emphasizing future trends. It's flexible, modifiable, and can include new indicators for future technologies. The framework benefits municipalities, RE developers, contractors, and owners in building SCs and SRE and aids in making informed investment decisions. Researchers and other entities can also use it to evaluate and develop smart developments. It evaluates existing cities and real estate to determine their current status and identify measures to increase their smartness. Additionally, it helps in planning SCs and SRE by providing a roadmap and requirements for their creation.

4.1.2 Evaluation Framework Development Process

The evaluation framework for SCs and SREs is constructed on multiple layers, analyzing existing classifications and SC components. Seven interrelated categories were selected: smart governance, smart people, smart infrastructure, smart energy, smart environment, smart technology, and RED status. Both SCs and SRE share these main categories. The framework also includes sub-categories with specific indicators chosen based on theoretical background, desk studies, indexes, and other publications. At the SC level, indicators were selected based on SC components, solutions, and technologies. Evaluation schemes like Smart City Index (SCI 2021), City in Motion Index (CIMI 2020), EU Taxonomy 2020, (Kaluarachchi, 2022), and (Shari, 2020) significantly influenced the selection process, along with other frameworks and

references. At the SRE (project) level, indicators were based on SRE components, solutions, and technologies. Schemes like SBISC (Apanaviciene et al., 2020), Jain's smart building evaluation system (Jain, 2019), and the Big 9 study (Ullah et al., 2018) played a major role, alongside other indexes, tools, Sustainability certification such as LEED and BREEAM and references including EU Taxonomy 2020 and the EU Smart Readiness Indicator (SRI) scheme. Both frameworks consist of seven categories, each containing multiple sub-categories. Each sub-category includes several indicators, with each indicator assigned a weighted score based on its importance and relevance to the evaluation criteria.

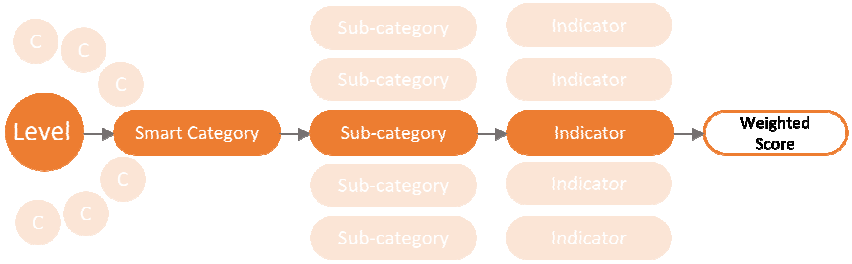

Fig. 3: Evaluation Framework Main Elements Illustration, Author, 2025.

The indicator score is determined based on its importance and relevance. The justification and scoring criteria incorporate several elements and are primarily derived from three sources. Indexes: the score is based on published indexes and subsequently calculated according to the indicator weight. figures and percentages: the score is derived from element counts or percentages, categorized within a developed range specific to each indicator, and scored accordingly. Various sources: utilized for indicators with multiple elements that cannot be evaluated based on a single element, where each element and source is listed, representing specific points, providing a maximum achievable score for the indicator. For all sources, the minimum and maximum performance are considered to develop a proper and realistic scoring and evaluation System.

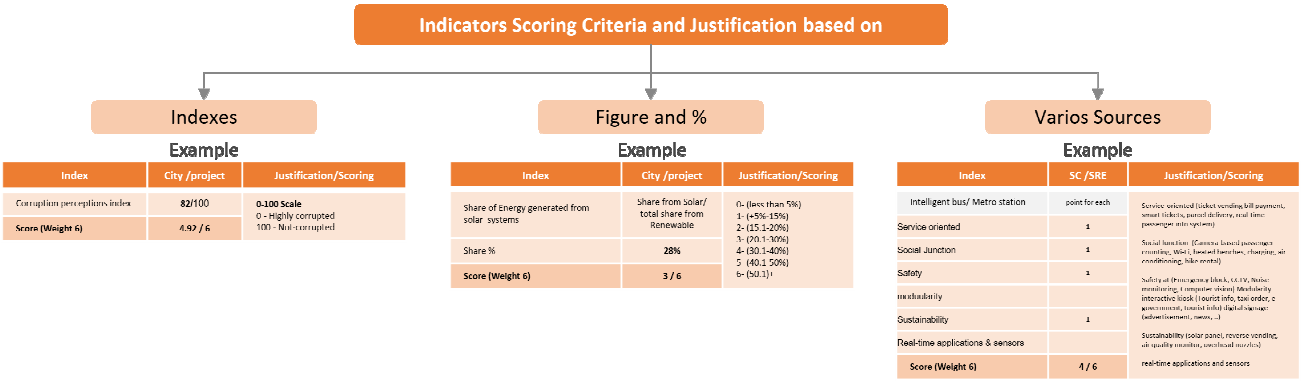

Fig. 4: Scoring Justification and Sources, Author, 2025.

4.2 Evaluation Framework

4.2.1 City Level

A total of 28 sub-categories and 85 indicators were used to evaluate the SC. The weighted score of each indicator is among these ranges (4, 6, 8, 10 points), it is identified based on its importance and relevance to the evaluation criteria. The total score was 560 points, distributed equally, with 80 points for each category.

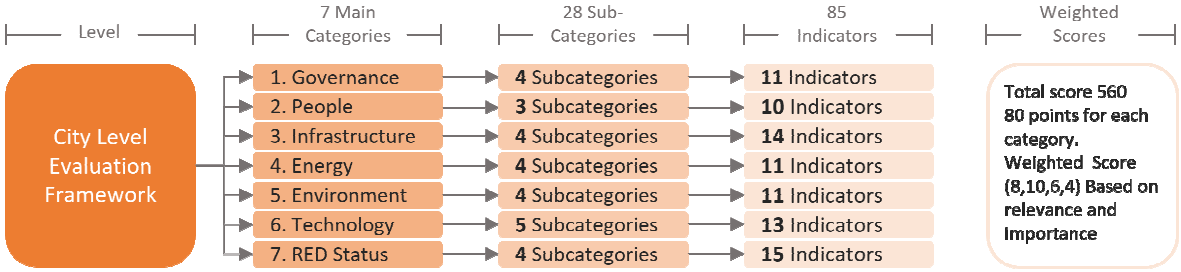

Fig. 5: Smart City Level Evaluation Framework Main Elements, Author, 2025.

Figure 6 represents a simplified illustration of the SC level evaluation framework, based on the developed framework of the authors (Al-Rimawi & Nadler, 2023) illustrating the main categories and sub-categories, with hints of the number of indicators, sub-category scores, and category score, to briefly represent which areas does the framework cover and target.

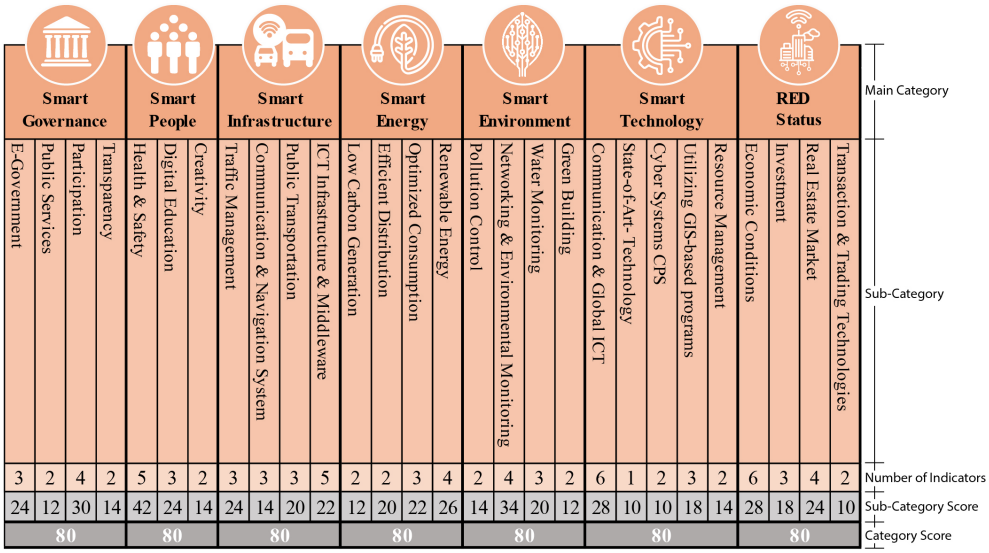

Fig. 6: Smart City Level Simplified Evaluation Framework, Author, 2025.Based on (Al-Rimawi & Nadler, 2023)

4.2.2 Real Estate (Project) Level

The smart project was evaluated using 90 indicators across 28 sub-categories, with an overall score of 255 points, distributed based on their relevance to SRE. Central to SRE, smart technologies had the highest share with 60 points. Smart energy and smart environment received 40 points each, while smart infrastructure and RED status had 35 points each. Smart people and smart governance, with indirect relevance, received 30 and 15 points, respectively. Each indicator's score weight was determined based on its importance and relevance to the SRE evaluation criteria, the weighted score is among these range of (1 – 5 points). It is worth noting that the ranges and total scores in the evaluation frameworks of the city level are different, to be able to assess elements at a more focused range, the maximum score at the project is out of 5, but in the calculations and measurements the results are based on percentages, where the range is not affected by the importance of the scale, it is only used for suitability in calculations, to ease the evaluation system for each case.

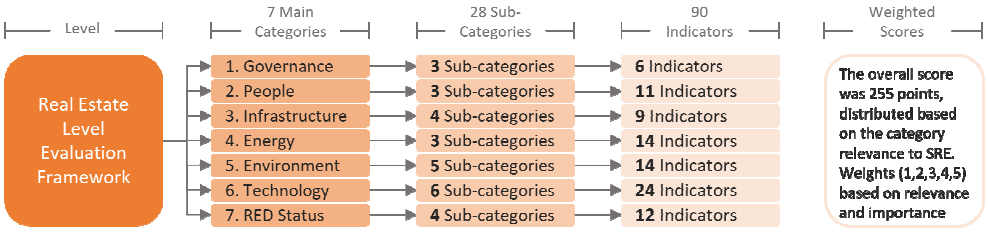

Fig. 7: Smart Real Estate (Project) Level Evaluation Framework Main Elements, Author, 2025.

The SRE level evaluation framework is represented in a simplified illustration in Figure 8, based on the developed framework by Al-Rimawi and Nadler (2023), illustrating the main categories and sub-categories, with hints of the number of indicators, sub-category scores, and category score, to briefly represent which areas does the framework cover and target.

5 BENCHMARKS ANALYSIS

The benchmark analysis was vital for this study to test the evaluation framework, understand how SC functions, and determine their impact and integration with SRE. It provides insights that help define SC principles in both theory and practice, aiding in the assessment of smartness status worldwide.

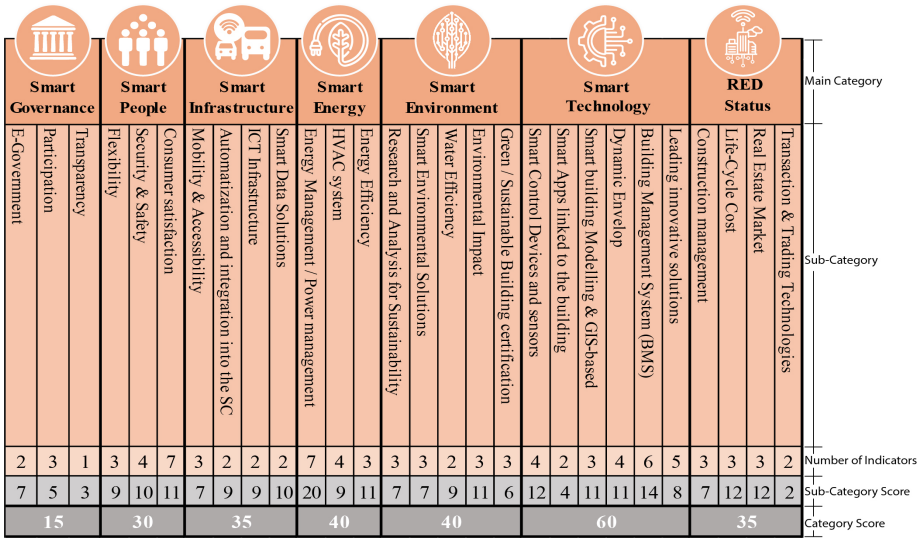

Fig. 8: Smart Real Estate Level Simplified Evaluation Framework, Author, 2025.Based on (Al-Rimawi & Nadler, 2023)

5.1 Benchmarks Selection Criteria

Table 1 illustrates the selection criteria for both levels. These benchmarks aim to identify and measure the current status of leading SCs and SREs. This provides insights into achievements and areas needing improvement and sets realistic goals for cities and projects within today's smart market.

Level	Criteria		Description	Justification
Smart City Level	Location		Worldwide/different continents	To measure location impact
	Scale		Diverse scale	To measure scale impact
	Population		More than 1.5M	To obtain large-sized cities
	Smartness		Include minimum core components	To locate SC
	Smart Technology		Utilizing smart technologies	To ensure suitability as an SC.
	Indexes	Smart City Index 2021	Ranked within the top 60–118	To ensure suitability as an SC.
		Cities in Motion Index 2020	Ranked within the top 60–174	To ensure suitability as an SC.
		The Global Financial Centres Index GFCI -2022	Ranked within the top 60–119	To capture a leading financial center, reflecting the financial aspect
		Innovation Cities 2021	Ranked within the top 60–500	To integrate innovative solutions
		Quality of Living City Ranking	Ranked within the top 60–231	To ensure adequate quality of life
Smart Real Estate Level	Location		In the selected Smart City	To ensure a clear SC/SRE link
	Project Type		Commercial RE project	To identify impact factors on RE
	Scale		Building scale	To assess projects at a transitional scale
	Project Status		Implemented	To evaluate the project operation Utilizing
	Smart Technologies		Utilizing Smart technologies as part of its operations	To ensure smartness and to be linked to SC
	Sustainability		Certified LEED or equivalent	Ensure Sustainability

Table 1: Benchmark Selection Criteria Description and Justification, Author, 2025.

5.2 Selected Benchmarks

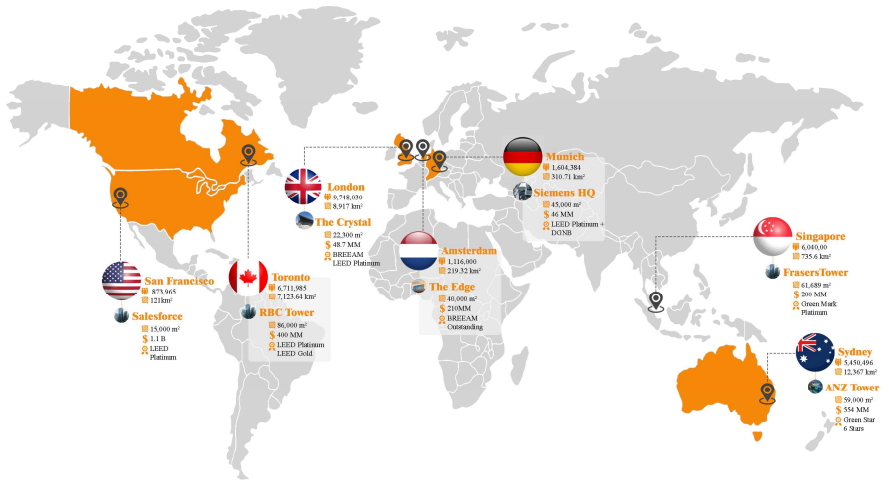

Fig. 9: Selected Benchmarks noth levels, Author, 2025.

Seven SRE were selected within seven SCs as shown in figure 9. The Edge in Amsterdam is the world's smartest and greenest building, achieving a 98.4% BREEAM score in 2015. It features IoT-based smart technologies, an efficient aquifer thermal energy storage system, and 28,000 sensors. The Crystal in London is the first building to achieve both Outstanding BREEAM and Platinum LEED accreditations. It adapts to the environment, generating 20% of its energy using photovoltaic cells. Siemens Headquarters in Munich is a certified Platinum LEED and DGNB building, using geothermal and photovoltaic systems for energy efficiency. Frasers Tower in Singapore is Green Mark Platinum-certified, with sustainable solutions and real-time data management. ANZ Tower in Sydney has a 6 Star Green Star rating, integrating smart grid and ventilation technologies. Salesforce Tower in San Francisco is LEED Platinum pre-certified, with sustainable solutions and a converged network. Using energy-efficient and sustainable design, RBC Waterpark Place in Toronto achieved LEED Platinum CandS and LEED Gold for OandM certifications.

6 RESULTS AND DISCUSSION

Based on the evaluation frameworks, London ranks as the smartest city among selected benchmarks with a score of around 70%, while the average SC level score is 65%. The Edge in Amsterdam ranks as the smartest RE, scoring 84%, with the average benchmark score being 72%. The framework aims for ultimate performance, considering future evolution. Only an ideal SRE in an ideal SC would achieve a full score, so the selected benchmarks are considered good to very good.

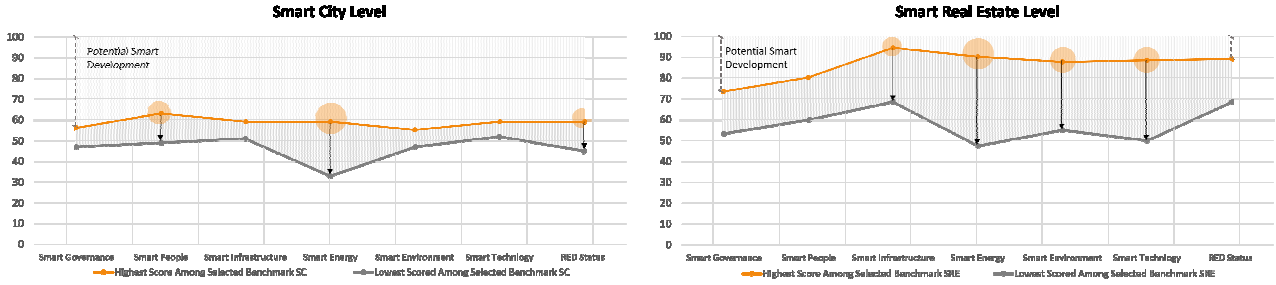

Fig. 10: Performance range between highest and lowest scores (city and real estate levels), Author, 2025.

Figure 10 shows the highest and lowest scores, creating a smart performance range to guide evaluators in assessing SCs and SREs. Some categories have insignificant range differences, while others, like smart energy, show significant drops, indicating potential technique failures or neglected elements. The evaluation framework revealed gaps in SCs and SRE, even for selected benchmarks. Further improvements are needed to reach a smarter state on both levels.

Figure 11 illustrates the SRE and SCs level performance in each smart category based on the average performance of the selected benchmarks. On average, the leading category at the SC level is smart technology and smart infrastructure for the SRE level.

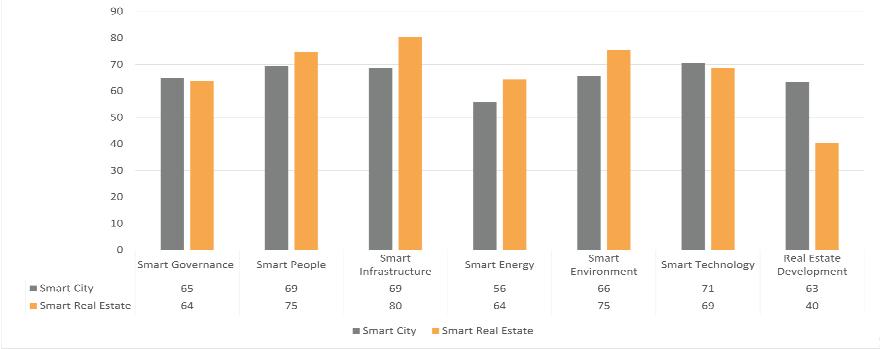

Fig. 11: Selected Benchmarks' average performance in the main smart categories, Author, 2025.

Figure 12 presents the sectional analysis of selected benchmarks' SRE integration into SCs and the performance of both levels in each category. SREs in Amsterdam, Munich, and London followed a leading strategy, being more developed than several SC categories. Projects in Singapore and Toronto adopted the following strategy, enhancing existing elements and exceeding in some areas. San Francisco and Sydney SREs followed the waiting strategy. The analysis shows that SC performance limits smart governance at the SRE level, with no selected SRE exceeding that limit. On average, projects adopted the leading strategy in

RED status, smart people, and smart infrastructure, and the following strategy in smart governance, smart environment, and smart energy. Smart technology followed the waiting strategy, with a decline in performance, indicating that the SRE technologies are still behind the curve

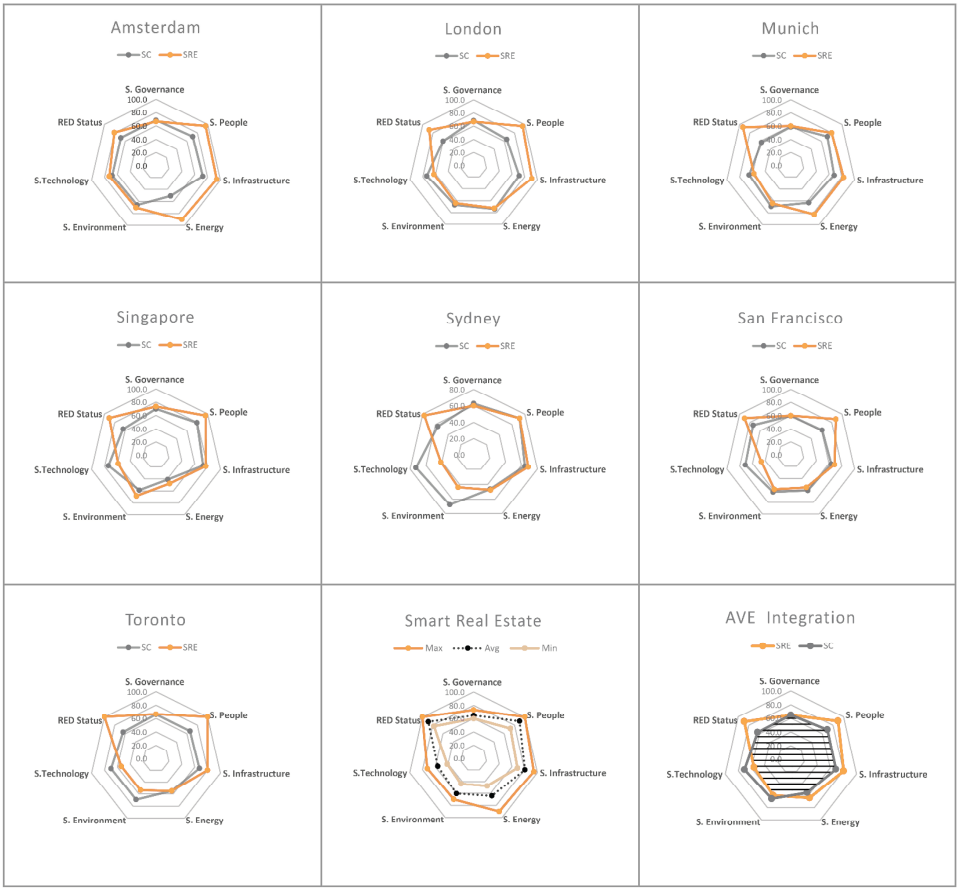

Fig. 12: Sectional analysis of selected Smart Real Estate integration into Smart Cities and the performance, Author, 2025.

In this study, a correlation analysis was performed on both SC and SRE levels and their integration using SPSS (Statistical Product and Service Solutions) software. The analysis covered three classifications: main categories, subcategories, and indicators. Results revealed significant integration and mutual impact between SC and SRE, with correlations detected across most elements. Notably, smart infrastructure, smart governance, and smart technology demonstrated the highest correlation and impact on various categories within both levels and their influence on each other.

Significant correlations were identified within the subcategory classification. At the SC level, e-government, transparency, and ICT infrastructure showed the highest correlations. At the SRE level, the highest correlations were found in ICT infrastructure, smart data solutions, and BMS. Integrated subcategories with high correlations included public transportation, transparency, cyber systems, mobility and accessibility, environmental impact, and smart apps linked to buildings.

7 CONCLUSION

The real estate sector is constantly evolving, requiring city management and developers to stay updated with advancements to create smart and leading developments. Both academic and practical sectors should invest in developing smarter cities and real estate through a coordinated approach. Given that smartness levels cannot be easily measured and compared, the developed evaluation tool addresses this issue by identifying the smartness level of cities and real estate developments. This tool provides clear gap identification, allowing stakeholders to focus on enhancing smartness.

This study developed and applied a comprehensive evaluation framework for smart cities (SC) and smart real estate (SRE), comprising 85 and 90 indicators, respectively. Applied to seven benchmarks per level, the analysis showed that cities and real estate developments are adopting smart principles and progressing towards smarter statuses. The smart performance of selected benchmarks ranged from good to very good,

with SRE projects achieving an average of 72% and SCs averaging 65%. Achieving a full score would not be realistic; only an ideal smart real estate in an ideal smart city could reach that score.

The results indicated a high correlation between smart cities and smart real estate developments, highlighting the necessity of investing in both scales as their impact is proportional. The development strategies varied: three projects followed a leading strategy, two adopted a following strategy, and two employed a waiting strategy. On average, smart real estate tends to adopt the leading strategy, except in smart governance, technology, and environment. To achieve smarter development and improve users' quality of life, efforts should focus on enhancing both levels due to their significant interdependence.

Future research should integrate the evaluation framework with existing systems such as SmartScore certification and smart building certification, adapting to evolving technology. This flexible framework can evolve into a recognized rating and certification system for smart cities and real estate, guiding municipalities, developers, and stakeholders in making informed investment decisions.

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