

Evaluation of Space Efficiency, Structural Systems, Material Applications, and Design of High-rise Structures in South Korea



by Kurt Orkun Aktaş, Ajda Zaim, Özlem Nur Aslantamer,
Gözen Güner Aktaş and Hüseyin Emre Ilgın

Cite this Article

Aktaş, K. O., Zaim, A., Aslantamer, Ö. N., Aktaş, G. G., & Ilgın, H. E. (2025). Evaluation of Space Efficiency, Structural Systems, Material Applications, and Design of High-rise Structures in South Korea. *Highlights of Sustainability*, 4(4), 256–284.

<https://doi.org/10.54175/hsustain4040016>

Highlights of Science

Publisher of Peer-Reviewed Open Access Journals

📄 <https://www.hos.pub>

Barcelona, Spain

Evaluation of Space Efficiency, Structural Systems, Material Applications, and Design of High-rise Structures in South Korea

Kurt Orkun Aktaş¹, Ajda Zaim², Özlem Nur Aslantamer²,
Gözen Güner Aktaş³ and Hüseyin Emre Ilgin^{4,*}

¹ Department of Interior Architecture and Environmental Design, Faculty of Fine Arts, Kırıkkale University, Kırıkkale, Turkey

² Department of Interior Architecture and Environmental Design, Faculty of Art, Design and Architecture, Atılım University, Ankara, Turkey

³ Department of Interior Architecture and Environmental Design, Faculty of Fine Arts, Design and Architecture, Başkent University, Ankara, Turkey

⁴ School of Architecture, Faculty of Built Environment, Tampere University, 33720 Tampere, Finland

* For correspondence: emre.ilgin@tuni.fi

Abstract This study examines 61 South Korean towers, analyzing their architectural configurations, structural systems, material applications, and spatial efficiencies. Findings indicate a predominance of central core configurations and prismatic forms, reinforcing a function-driven approach to vertical urbanism. Structural system preferences highlight the widespread use of out-riggered frames, ensuring lateral stability while optimizing floor layouts. Material selection trends reveal a reliance on concrete, aligning with global patterns, while composite materials (25%) are used in high-performance supertall structures. Functionally, residential high-rises dominate, with mixed-use (2%) and office towers (11%) remaining limited. This research also identifies an average spatial efficiency of 76%, aligning with international benchmarks, though variations exist across cities due to core-to-gross floor area ratios, structural constraints, and service core allocations. This research underscores South Korea's strategic high-rise development, prioritizing space optimization, structural efficiency, and economic feasibility. However, opportunities remain for increased functional diversity, broader hybrid material adoption, and greater integration of sustainable design innovations. These findings contribute to global skyscraper analysis, offering insights into high-rise architecture's role in urban resilience and density management.

Keywords high-rise buildings; architectural design considerations; structural design considerations; space efficiency; South Korea

1. Introduction

Rapid urbanization and land scarcity have established high-rise buildings as a defining response to urban growth in global cities like New York, Shanghai, Singapore, and Dubai, where technological advancement, planning policy, and symbolic form converge [1–3]. The evolution of vertical architecture has been widely explored across themes, including structural innovation [4], environmental performance [5], urban morphology [6], mixed-use integration [7], and emerging areas such as timber high-rises [8–12].

In contrast, South Korea's prolific high-rise landscape—especially its residential towers—remains underexplored [13,14]. Despite the country's extensive vertical housing output, existing literature focuses on isolated cases [15], historical trajectories [16], or planning policies [17–19], lacking a cohesive analytical framework. Notably, space efficiency, a core performance metric in high-rise design, has received limited attention in the Korean context. While global studies increasingly use metrics like core-to-gross floor area (GFA) ratios and net-to-gross floor area comparisons to assess spatial optimization [20,21], Korean research remains largely descriptive [22,23], seldom benchmarking against international norms.

Additionally, prior studies emphasize iconic supertall structures [24,25], overlooking the mid-to high-rise residential typologies that shape everyday urbanism in Korea. Though architecturally restrained, these towers are critical to understanding urban density, spatial rationalization, and construction logic.

This study fills that gap by offering a data-driven, comparative analysis of how design and structural decisions affect space efficiency in Korean high-rises. Unlike global research focused

Open Access

Received: 11 July 2025

Accepted: 11 November 2025

Published: 26 November 2025

Academic Editor

Monto Mani, Indian Institute of Science, India

Copyright: © 2025 Aktaş et al.

This article is distributed under the terms of the [Creative Commons Attribution License](#) (CC BY 4.0), which permits unrestricted use and distribution provided that the original work is properly cited.

Highlights of Science

on landmark towers, this study centers on the dominant yet understudied residential typology in Korea. It introduces a four-pronged framework examining: Space efficiency, using metrics like average usable area and core-to-GFA ratios; Structural systems, analyzing their relationship to function and internal layout; Material use, identifying how structural choices influence performance; Architectural design, assessing the impact of form, core configuration, and program on spatial optimization.

Through empirical benchmarking and comparative analysis, this study contributes to performance-based architectural discourse and offers insights into how dense vertical urbanism can be optimized without compromising structural logic or regulatory alignment [26,27].

2. Literature Survey

Optimizing spatial efficiency in high-rise buildings is a key concern in contemporary architecture and engineering, driven by urban densification, land scarcity, and sustainability goals. Enhancing usable floor areas while minimizing structural and functional constraints ensures both economic viability and environmental responsibility [28]. Recent theoretical work by Mobaraki & Oktay Vehbi [29] emphasizes that spatial efficiency cannot be isolated from sustainable urban morphology, showing that compact, vertically layered forms enhance ecological and social performance.

Structural innovations such as core-outrigger systems, diagrids, and mega-structures enhance lateral stability while enabling open floor plans, as exemplified by the Guangzhou CTF Finance Centre with its mega-columns and outrigger truss [30]. Residential skyscrapers require adaptable layouts due to diverse unit configurations, where modular designs and flexible partitions improve both functionality and social cohesion, as seen in Marina One, Singapore [31]. Aerodynamic shaping techniques like tapering and twisting mitigate wind loads while supporting efficient interior layouts, as in the Turning Torso [32–35]. Mixed-use skyscrapers integrate multiple functions through vertical zoning and shared infrastructure, as in Taipei 101 [36]. Similarly, Dizdaroglu [37] highlights how sustainable open-space design principles—particularly those enhancing biodiversity and microclimatic regulation—can reinforce spatial efficiency and livability within dense urban environments.

Supertall residential buildings must balance efficiency with livability. Ilgin [38] highlights strategies such as optimized floor plates, multifunctional spaces, and decentralized HVAC systems, complemented by innovative materials like high-strength concrete and lightweight steel, demonstrated in the Petronas Towers [39]. Social and functional considerations, including communal areas, flexible layouts, and green spaces, further align high-rise design with user-centered principles [40,41]. Biswas et al. [42] support this argument through mathematical modeling, demonstrating that optimized green-building configurations under climate change can reduce urban carbon emissions by 20–40%, linking efficiency directly to environmental sustainability.

Contextual factors also shape tall building practices. South Korea's mountainous terrain and limited flat land drive compact urban development in cities such as Seoul, Busan, and Incheon [43–45]. Its humid continental and subtropical climate has informed adaptations, reinterpreted in modern high-rises with advanced insulation, high-performance glazing, and climate-responsive façades [46–48]. Resilience is critical due to exposure to typhoons, heavy rainfall, and seismic risk; structural responses include shear walls, outrigger frames, and flood-resilient foundations [49]. Sustainability strategies such as green roofs, rainwater harvesting, and energy-efficient HVAC systems are increasingly adopted, with Songdo International Business District serving as a notable example [50,51]. Muhy Al-Din et al. [52] further propose a hybrid thermal comfort model combining objective and subjective evaluation metrics, showing that east-oriented towers achieve optimal comfort in semi-arid climates, thereby informing orientation and façade design for future high-rises.

Governance frameworks differ across regions. South Korea adopts a decentralized approach, as seen in Seoul's 2030 Urban Plan and Songdo's Smart City Initiative [53–55], while Shanghai operates under a top-down model, with its Master Plan 2035 driving sustainable growth and large-scale transformations like Pudong [56–60]. Korea's Green Building Certification System (G-SEED) further institutionalizes sustainability through mandatory energy and environmental standards [61–63]. Complementary research by Saadatjoo & Ahmad Nia [64] demonstrates that adaptive regulatory strategies—such as incorporating insulation, double glazing, and shading systems—are essential for long-term building resilience under climate change scenarios.

Recent advances in structural optimization emphasize not only performance but also

constructability and sustainability. Lacidogna et al. [65–67] demonstrated how diagrid geometries and coupling with shear walls influence lateral, torsional, and dynamic behavior. Cucuzza et al. [68,69] shifted focus from weight minimization to constructability, showing that design strategies integrating standardization and cutting-stock optimization can reduce material waste by up to 40%. Extending this, Di Bari et al. [70] reviewed resilience–sustainability linkages and proposed a two-step life-cycle framework integrating structural robustness, cost, social, and environmental metrics. Together, these studies mark a paradigm shift from isolated optimization toward holistic frameworks combining efficiency, resilience, and sustainability.

Despite extensive global research, systematic evaluation of space efficiency in South Korean towers remains limited. Existing studies emphasize landmark cases or broad typologies, with little use of empirical metrics such as core-to-GFA ratios or net-to-gross floor area. Frameworks benchmarking Korea’s residential-heavy, prismatic, central-core typologies against regions like Shanghai, Singapore, or the Middle East are notably absent. Moreover, Korean scholarship rarely integrates form, structure, material, and spatial performance within climatic and regulatory constraints.

In summary, previous research has offered insights into tall building development across structure, spatial strategies, materials, and climate adaptation, yet remains fragmented and largely descriptive, with limited synthesis of parameter interdependencies. This study addresses that gap by analyzing 61 South Korean high-rises through standardized metrics and developing a transferable framework linking architectural, structural, and spatial parameters to broader urban debates.

3. Research Method

This study adopts a case study methodology (Figure 1) to examine space efficiency in 61 tall buildings across South Korea, using data from the Council on Tall Buildings and Urban Habitat (CTBUH) database [71]. Recognized for its global research on urban density and vertical growth, CTBUH provides comprehensive data relevant to sustainability and high-rise development [72].

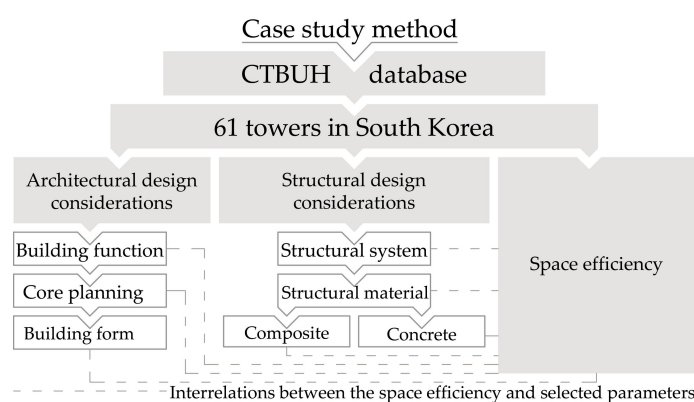


Figure 1. Data-processing sequence and key analytical parameters of the study. The flowchart illustrates the systematic workflow from data collection using the CTBUH database through multi-stage case selection, parameter coding (e.g., form, structure, and function), and validation, leading to the comparative analysis of space-efficiency metrics (NFA—net floor area/GFA and core-to-floor ratios) across 61 towers.

Although the CTBUH database and related compilations served as the primary source for identifying tall buildings, all data points were systematically cross-verified using municipal planning archives, developer and architectural firm publications, and peer-reviewed case studies to ensure accuracy and completeness. Beyond descriptive cataloging, the study applied a standardized coding framework to each tower, including net-to-gross floor area ratios, core-to-floor metrics, functional distribution, and structural/material categories. This coding scheme enabled systematic comparison across 61 projects and facilitated the development of an analytical framework linking design, structural, and spatial parameters. By combining rigorous cross-validation with a replicable coding system, the methodology advances beyond secondary-data reliance and offers an innovative, data-driven approach to high-rise research.

To ensure data reliability, transparency, and comparability, a structured three-stage validation procedure was adopted. First, all 61 towers were identified and screened through the

CTBUH database (2024 update) using consistent filters for height (over 150 m), function (residential, office, or mixed-use), and completion year (2000–2025). Second, for 24 towers (approximately 40% of the sample), data on floor areas, structural systems, and completion details were cross-verified using municipal building permit archives in Seoul, Busan, Incheon, and Daegu, complemented by developer-issued architectural reports and building information models (BIM). Third, the remaining cases were validated against peer-reviewed architectural case studies and academic publications indexed in Scopus and KCI to ensure typological and dimensional consistency with CTBUH records. This triangulated approach confirms that the study's dataset is not solely dependent on CTBUH data but is empirically substantiated by multiple verifiable sources, strengthening both reproducibility and methodological coherence. The exclusion of European cases followed the same logic of methodological consistency: due to divergent building codes, definitions of gross floor area, and incomplete CTBUH entries, including them would have compromised the analytical comparability of the dataset. Concentrating instead on Asia and North America—where high-rise development is extensive, data completeness is higher, and typologies are more systematic—enhances the internal validity and analytical precision of the comparative framework.

Comparative analysis deliberately excludes Europe. Unlike East Asia, the Middle East, or North America, where tall buildings constitute a dominant feature of contemporary urban growth and urban identity, European high-rises remain relatively rare, geographically dispersed across multiple cities, and generally limited to specific financial or business districts [73]. Their development has also been constrained by stringent planning regulations, height restrictions, heritage preservation policies, and cultural resistance to vertical expansion. Consequently, tall buildings in Europe often function as isolated landmarks rather than forming systematic urban typologies, which reduces the value of direct comparison with the South Korean dataset. Including them would therefore dilute the analytical consistency of this study, whereas focusing on regions where high-rise construction is both extensive and systematic—such as East Asia, the Middle East, and North America—ensures a more coherent and robust comparative framework.

Selection criteria focused on buildings completed within the last 25 years to ensure a contemporary analysis. The sample includes various functional typologies, such as the Busan International Finance Center Landmark Tower (289 m). Buildings without detailed space efficiency data or accessible floor plans were excluded to ensure analytical accuracy.

The methodological framework involved a systematic evaluation of architectural layouts, including typical floor configurations, lower sections, and ground levels. Space efficiency was assessed through the NFA to GFA ratio, a critical metric for optimizing usable interior spaces. Key influencing factors included structural systems, building form, and floor slab organization. South Korean high-rises emphasize minimizing structural obstructions to maximize interior flexibility, with lease span—measuring the distance between core walls and the building envelope—playing a crucial role in layout adaptability [28].

The selected case studies illustrate diverse architectural strategies for optimizing space. Parcel Tower II, for instance, employs an outriggered frame system with a setback design, enhancing both structural stability and interior efficiency [25]. Other buildings feature configurations tailored to local market demands, ensuring adaptability in high-density urban settings. These findings underscore the interplay between architectural planning and structural design in maximizing space efficiency in contemporary high-rises [74,75].

The spatial distribution of tall buildings in this study, illustrated in Figure 2, underscores their concentration in six major South Korean cities. Seoul, as the capital and financial center, exhibits the highest density, reflecting its dominance in vertical urban expansion. Busan, a key maritime and economic hub, and Goyang—a growing satellite city—also feature prominently. Incheon, with its Songdo International Business District, exemplifies smart city initiatives and mixed-use high-rise development. Hwaseong represents rapid industrial and residential growth, while Bucheon illustrates localized vertical expansion. This distribution provides a representative framework for analyzing high-rise development, structural innovation, and regional urban strategies.

This study examines 61 high-rise buildings to capture the architectural and structural diversity of contemporary South Korean skyscrapers while analyzing spatial efficiency trends. The curated dataset, detailed in Appendix A, includes residential, office, and mixed-use towers of varying heights and design philosophies. By incorporating a broad spectrum of buildings, the study provides insights into spatial utilization and functional dynamics in high-rise architecture,

particularly in the context of urban densification and spatial optimization challenges.

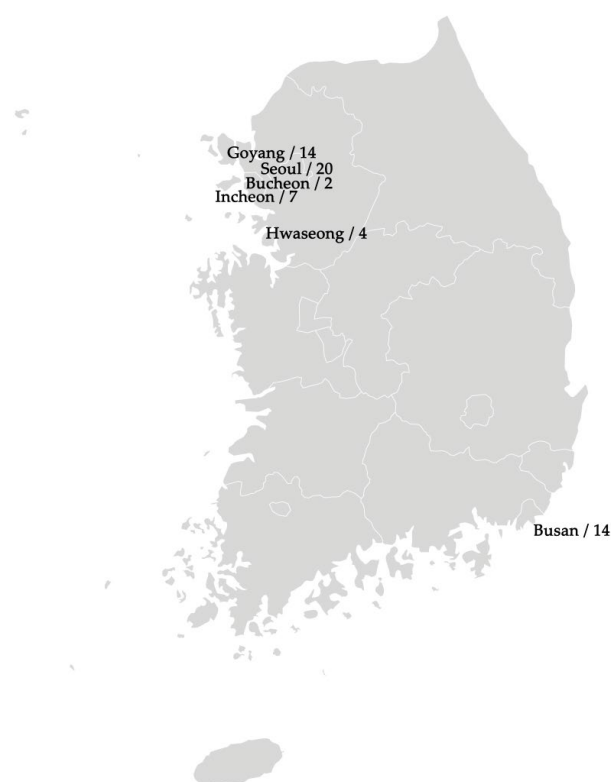


Figure 2. Map of towers in South Korea. Geographical distribution of the 61 analyzed towers across six cities, highlighting Seoul's dominance in high-rise density. Symbols represent tower locations.

A key criterion was selecting architecturally and functionally significant buildings that exemplify best practices in high-rise design. The sample spans early 21st-century towers, such as Tower Palace One (2002), to recent projects like Marina G7 Building and Acro Seoul Forest Tower (2021), allowing an analysis of evolving architectural trends, regulations, and technological advancements over 25 years.

The dataset also includes diverse structural systems and core configurations to systematically classify building forms. This facilitates an in-depth exploration of height, form, and spatial efficiency relationships. Structural systems range from prismatic and free-form geometries to peripheral core configurations, integrating advanced materials such as reinforced concrete, steel frameworks, and hybrid composite systems ([Appendix B](#)).

The dataset in [Appendix B](#) reveals a predominant reliance on outriggered frame systems, widely used to enhance lateral stability and interior flexibility. ParcI Tower II, FKI Tower, and Seoul Hall TP Tower exemplify this system in high-rise office developments, while residential towers like Tanhyun Doosan We've the Zenith 105 and Ilsan Yojin Y-City Tower 103 employ similar strategies to optimize load distribution and maximize usable space. These systems mitigate lateral forces from wind and seismic activity while enabling column-free interiors, reinforcing their widespread application in skyscraper design.

Shear-walled frame systems, in contrast, provide rigidity and structural integrity, particularly in residential and mixed-use developments. Examples include Marina G7 Buildings A and B, Songdo Posco Centroad Tower 1, and Daesung D-Cube City Headquarters, where reinforced concrete shear walls enhance seismic resilience while balancing spatial efficiency [76].

Curated Data and Analysis: Architectural, structural, and stakeholder-sourced data ensured precision in space efficiency assessment. Floor plans were standardized for comparative evaluation ([Appendix C](#)), with core areas analyzed for their impact on the net-to-gross floor area (NFA/GFA) ratio. Conrad Seoul (88% efficiency) exemplifies an optimized layout, while Songdo Posco Centroad Tower 1 (63%) allocates excessive space to service cores, reducing efficiency.

Buildings lacking structural data or floor plans were excluded. As detailed in [Appendix C](#), outriggered frame structures (e.g., Tanhyun Doosan We've the Zenith Towers, 78%) enhance structural balance and spatial flexibility, whereas shear-walled frames (e.g., Marina G7 Buildings,

72%) prioritize seismic resilience at the cost of usable space.

South Korean high-rise planning follows global trends [77,78], where core configurations, functional requirements, and material choices dictate spatial strategies. Given the country's mountainous topography and dense urban fabric, compact, high-efficiency designs maximize usability while ensuring structural integrity.

Figure 3 classifies core layouts into central, atrium, external, and peripheral types, each shaping spatial organization and functionality, as summarized below [79–82]:

- Central core is centrally positioned in the building, uniting structural stability and compact planning with architectural openness for light and views, while ensuring safety through efficient evacuation routes.
- Atrium core is an advanced central core that combines efficiency with daylight and ventilation benefits, but it demands extra fire-safety measures due to the chimney effect.
- External core is a detached element linked to the building, offering thermal buffering and energy savings, but limited by emergency access and circulation inefficiencies.
- Peripheral core is located at the building edge, offering open-plan layouts and thermal buffering for energy efficiency, but its drawbacks include longer circulation paths and limited fire-escape effectiveness.

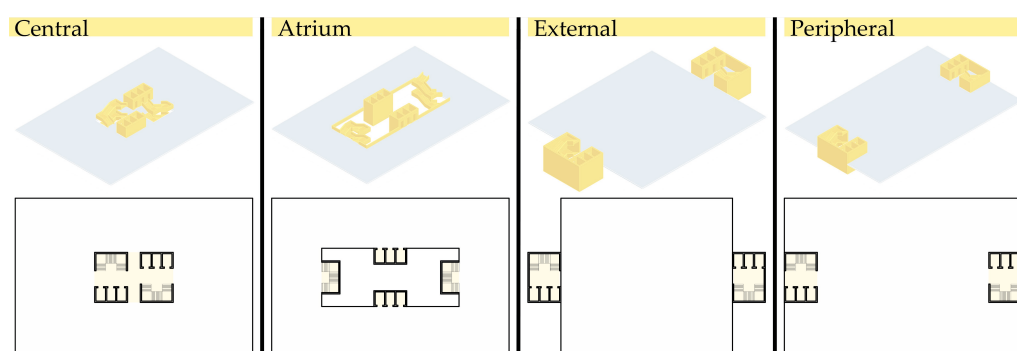


Figure 3. Typologies of core layouts. Classification of high-rise cores into central, atrium, external, and peripheral types. Icons illustrate schematic arrangements of cores and service areas.

Figure 4 outlines six primary skyscraper form typologies—prismatic, setback, tapered, tilted, twisted, and free-form—each shaping structural behavior, spatial use, and visual identity, as summarized below [83,84]:

- Prismatic forms denote buildings characterized by parallel and equal end faces, uniform side profiles, and a strictly vertical central axis, thereby producing a geometrically regular volume.
- Setback forms describe towers that incorporate horizontally recessed segments at successive heights, creating a stepped profile.
- Tapered forms are distinguished by a progressive reduction in floor plate size and surface area with increasing height, resulting in either linear or curvilinear narrowing.
- Tilted forms refer to buildings whose mass is intentionally inclined away from the vertical.
- Twisted forms emerge from the incremental rotation of floors or façades around a vertical axis, achieved by applying a consistent twist angle as the structure rises.
- Free forms encompass all other geometries that do not conform to these conventional typologies, often embracing irregular or highly expressive volumetric configurations.

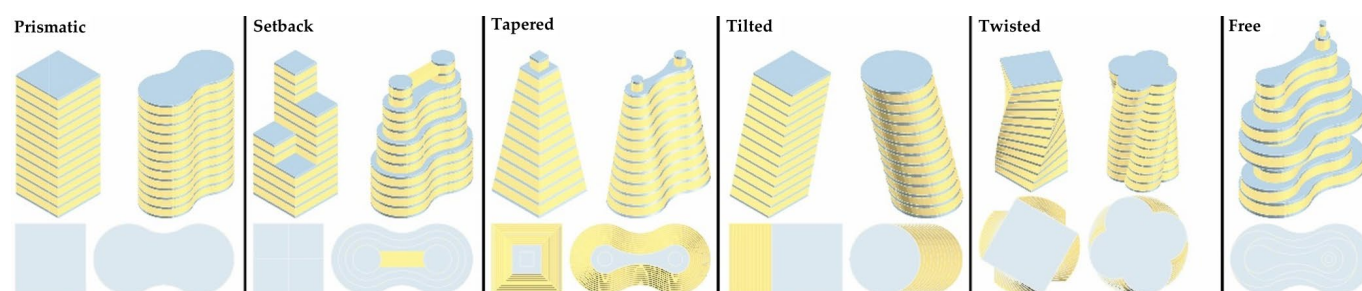


Figure 4. Typologies of form. Six main skyscraper form categories (prismatic, setback, tapered, tilted, twisted, free-form) with diagrams showing their geometric characteristics.

Each core and form typology addresses distinct functional, aesthetic, and environmental challenges in high-rise architecture. Appendix B details 61 selected buildings, documenting their core configurations, structural systems, and material selections. The study highlights the necessity of selecting appropriate typologies to balance architectural innovation with structural efficiency, ensuring both aesthetic appeal and functional optimization.

The structural framework plays a crucial role in maximizing space efficiency, influencing spatial organization, structural dimensions, and overall performance. As illustrated in Figure 5, structural systems are categorized, each optimizing spatial utilization and load distribution, as summarized below:

- Shear frame: A composite structural scheme integrating shear walls or trusses with rigid frames, further classified into *shear-trussed* and *shear-walled frames*.
- Mega column: A system employing oversized columns or shear walls—significantly larger in cross-sectional dimensions than standard members—that extend uninterrupted across the tower's height, acting as dominant vertical load-bearing components.
- Mega core system: A vertical structural concept in which a core with substantially enlarged cross-sections compared to conventional practice extends continuously through the building height, serving as the principal load-resisting element.
- Outriggered frame: A configuration where deep outrigger elements, typically spanning at least one full story, connect the central core to exterior columns or walls, thereby enhancing global stiffness and resistance against lateral loads.
- Tube:
 - *Framed-tube*: Formed by closely spaced perimeter columns rigidly connected through spandrel beams, producing a stiff tube-like façade.
 - *Trussed-tube*: Similar to the framed-tube but incorporating exterior multi-story diagonal braces, improving efficiency against lateral forces.
 - *Bundled-tube*: A cluster of two or more tubes integrated to act together as a unified structural system, offering enhanced redundancy and architectural flexibility.
- Butressed core: A refined evolution of the shear wall system, where shear walls are directly linked to and reinforce the central core, thereby significantly improving its lateral stability.

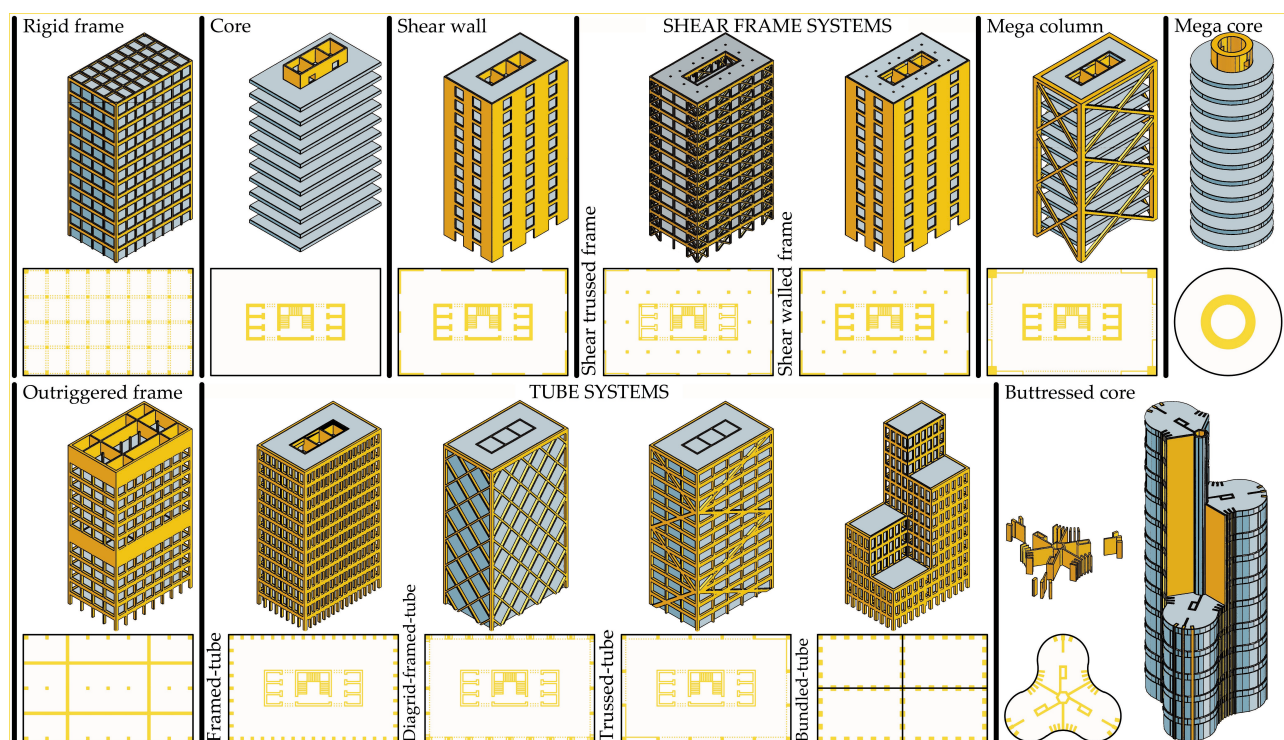


Figure 5. Typologies of structural systems. Comparison of shear frames, mega column & core, outriggered frame, tube, and buttressed core systems. Schematics illustrate how each system distributes lateral and vertical loads.

Material selection also impacts element sizing and configuration, with steel, concrete, and composite systems dominating high-rise construction. Composite structures, combining the compressive strength of concrete with the tensile capacity of steel, enhance load-bearing efficiency while minimizing material volume, thereby optimizing interior space.

In this study, the term “composite” refers to tall buildings where the main structural members—columns, beams, shear walls, trusses, or outriggers—are either divided between reinforced concrete and steel (member-based) or formed by combining both materials within the same section (cross-section based), or a mix of these approaches.

In high-density cities, space efficiency—measured by the NFA-to-GFA ratio—is vital for both functional and economic performance. Efficient layouts not only enhance usability and sustainability but also drive financial returns in commercial and residential projects. Strategic core design minimizes service area losses, improving NFA-to-GFA ratios and overall spatial optimization [85]. Advanced vertical systems and high-performance materials further mitigate spatial constraints in dense contexts.

This study applies global standards (BOMA, RICS, IPMS) to evaluate space efficiency using two key metrics: NFA-to-GFA and core-to-GFA ratios. These quantify how effectively usable space is maximized relative to structural cores and service areas, offering an objective basis for performance assessment.

Among these, the NFA-to-GFA ratio is crucial—it reflects the proportion of revenue-generating, functional area within total floor space. Higher ratios signify more efficient, high-value designs [86]. In dense urban settings, maximizing this metric is essential for project viability. By aligning core configurations with innovative structural strategies, this study highlights the importance of international benchmarking in advancing spatial efficiency in tall buildings.

To ensure consistency in evaluation across the sample, two standardized space efficiency metrics were employed:

- Net-to-Gross Floor Area Ratio (N/G):

$$N/G = \frac{\text{Net(Usable) Floor Area}}{\text{Gross Floor Area}}.$$

This ratio represents the share of usable interior floor area in relation to the total gross constructed area.

- Core-to-Gross Area Percentage (C/G):

$$C/G = \left(\frac{\text{Core Area}}{\text{Gross Floor Area}} \right) \times 100.$$

Together, these ratios offer a consistent basis for comparing space efficiency across diverse building types.

4. Findings

This section outlines three major architectural design parameters and their interconnections with various design considerations in high-rise architecture. These parameters are as follows:

- Key architectural design parameters: function, core planning, and form;
- Key structural design considerations: structural material and systems; and
- Relation of space efficiency and key design considerations.

4.1. Key Architectural Design Parameters: Building Function, Core Planning, and Building Form

Figure 6 illustrates the functional distribution of the analyzed high-rises: 84% residential (51 buildings), 11% office (seven buildings), 3% hotel (two buildings), and 2% mixed-use (one building).

- Residential dominance reflects high urban housing demand, driven by rapid urbanization and land scarcity.
- Limited hotel and mixed-use developments suggest a lower emphasis on hospitality and integrated urban environments.
- Standalone residential and office buildings are favored over mixed-function towers, likely due to zoning regulations, market demand, and economic feasibility.

As shown in Figure 6, only 2% of the surveyed towers are mixed-use, while the overwhelming majority are single-purpose, mainly residential. This imbalance demonstrates South Korea's

strong preference for mono-functional towers, shaped by regulatory frameworks and market demand for standardized, cost-effective housing. To clarify this point, we revised the section to make explicit that the minimal share of mixed-use projects underpins our conclusion. More broadly, we refined the Findings so that each statistical trend—whether in cores, forms, structures, or materials—is followed by a brief explanation of its economic, regulatory, or cultural rationale, ensuring results are presented as insights rather than simple descriptions.

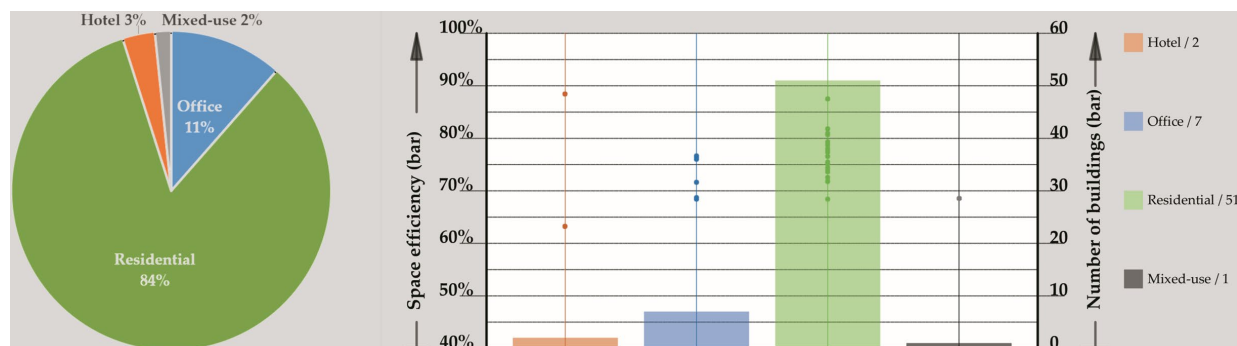


Figure 6. Functional distribution of the 61 surveyed South Korean high-rises. Space efficiency values refer to the individual buildings represented by each bar, while bar graph data should be read from the right axis.

All buildings selected in this study employ a central core configuration and are categorized as 84% residential (51 buildings), 11% office (seven buildings), 3% hotel (two buildings), and 2% mixed-use (one building), as illustrated in Figure 7.

The exclusive use of central cores highlights their adaptability, particularly in residential high-rises, where maximizing net floor area is a priority. In contrast, office and hotel buildings require larger service areas, affecting spatial efficiency. These findings emphasize how function-specific spatial needs shape optimization strategies, even within a consistent core typology, reinforcing the predominance of residential high-rises in urban development.

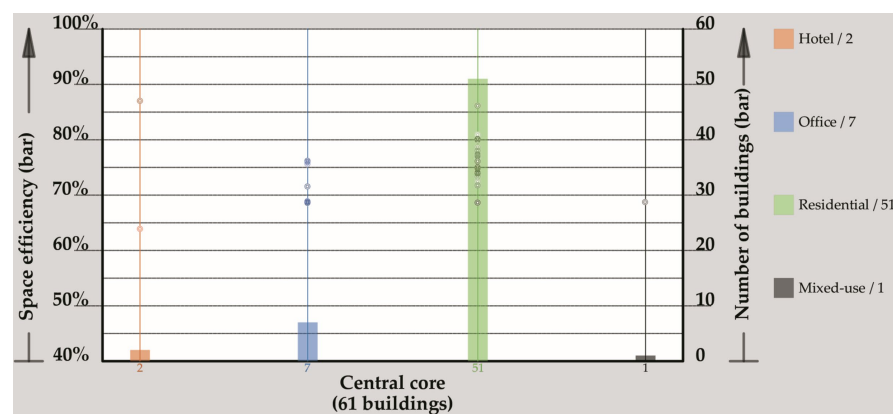


Figure 7. Core typologies across the sample towers. Space efficiency is shown for each building; the bar graph values correspond to the right axis.

Figure 8 highlights the dominance of prismatic buildings (95%), with free-form (3%) and setback (2%) structures being rare. Prismatic forms are favored because their regular geometry simplifies construction and structural calculations, allows efficient use of standard reinforced concrete and core systems, and maximizes floor plate regularity. This combination reduces construction and maintenance costs while increasing the proportion of usable space, making prismatic forms particularly attractive in South Korea's cost- and density-driven urban context. Free-form and setback buildings remain limited due to higher structural complexity, lower space efficiency, and increased costs. Setback forms, mainly shaped by zoning regulations, are underrepresented, indicating a preference for vertical continuity in urban planning. These findings confirm that economic feasibility, structural efficiency, and market demands drive the preference for pragmatic, high-efficiency designs over complex geometries in South Korea's high-rise developments.

Although Figures 6–8 may appear to reiterate data already described in the text, they collectively serve an analytical purpose by visually linking functional, core, and formal typologies.

Their sequential reading reveals how residential dominance aligns with central-core planning and prismatic geometries—an interrelation less evident through text alone. The figures thus operate as complementary analytical tools, transforming numerical patterns into visual arguments that clarify the systemic coherence of South Korea’s efficiency-driven high-rise model.

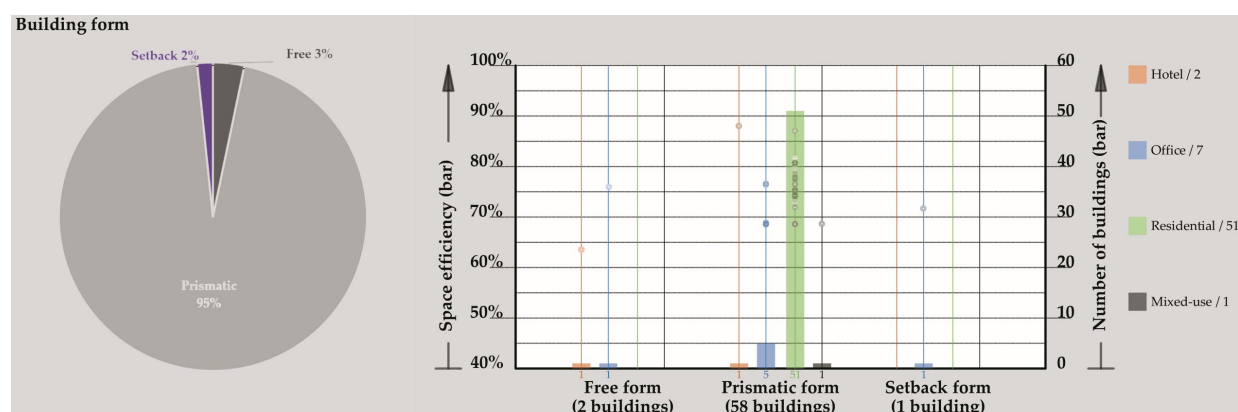


Figure 8. Formal typologies of the surveyed towers (e.g., prismatic, setback, free-form). Space efficiency values correspond to individual buildings; bar graph data must be read from the right axis.

Table 1 compares high-rise trends across Shanghai, Singapore [87], broader Asia [76], the Middle East [77], and North America [78], revealing marked regional contrasts in function, core typology, and form.

Table 1. Comparative overview of function, core type, and form across global urban centers.

	Findings	Shanghai [76]	Singapore [87]	Asia [76]	The Middle East [77]	North America [78]
Function	Mixed-use (2%)	Mixed-use (14%)	Mixed-use (10%)	Mixed-use (57%)	Mixed-use (33%)	Mixed-use (42%)
	Office (11%)	Office (77%)	Office (35%)	Office (38%)	Office (22%)	Office (32%)
	Residential (84%)	Residential (2%)	Residential (49%)	Residential (5%)	Residential (45%)	Residential (22%)
	Hotel (3%)	Hotel (7%)	Hotel (6%)			Hotel
Core Type	Central (100%)	Central (93%)	Central (79%)	Central (99%)	Central (96%)	Central (90%)
	Peripheral (0%)	Peripheral (7%)	Peripheral (21%)	External (1%)	External (4%)	Peripheral (10%)
Form	Prismatic (95%)	Prismatic (86%)	Prismatic (73%)	Prismatic (23%)	Prismatic (45%)	Prismatic (26%)
	Setback (2%)	Setback (3%)	Free (27%)	Setback (13%)	Setback (7%)	Setback (29%)
	Free (3%)	Twisted (2%)		Tapered (36%)	Tapered (7%)	Tapered (26%)
		Free (9%)		Twisted (1%)	Twisted (4%)	Free (19%)
				Free (27%)	Free (37%)	

South Korea shows overwhelming residential dominance (84%), contrasting with office-centric Shanghai (77%) and Asia (38%). North America (22%) and the Middle East (45%) reflect more balanced residential-commercial mixes, supported by integrated planning. Mixed-use towers are common in the Middle East (33%) and North America (42%), but rare in South Korea (2%). Hotels play a minor role overall, with modest presence in Shanghai (7%) and Singapore (6%).

Central cores dominate globally—South Korea (100%), Asia (99%), the Middle East (96%), and North America (90%)—for their efficiency and structural clarity. While Shanghai (93%) and Singapore (79%) also favor central cores, they exhibit notable use of peripheral systems (7% and 21%), allowing flexible interior layouts. External cores are scarce, appearing only in Asia (1%) and the Middle East (4%).

Prismatic forms are prevalent in South Korea (95%), Shanghai (86%), and Singapore (73%), emphasizing structural simplicity. Conversely, Asia (23%), the Middle East (45%), and North America (26%) show greater variety, with tapered (26–36%), twisted (4–12%), and free-form (19–37%) towers dominating landmark projects. Setback forms are more frequent in North America (29%) and Asia (13%), shaped by zoning and urban context, but rare in South Korea (2%) and Shanghai (3%).

Beyond their numerical representation, these distributions point to a deeply structured design logic in South Korea's high-rise architecture. The near-universal adoption of central cores and prismatic geometries suggests the emergence of a “functional–structural alignment” model, where form and core are not stylistic choices but performance-driven outcomes. This aligns with theoretical perspectives of modernist functional determinism, which argue that architectural typologies evolve through economic and regulatory adaptation rather than aesthetic experimentation. In this sense, Korea's mono-functional, efficiency-oriented towers embody a rationalized form of vertical urbanism—an architecture of optimization shaped by zoning codes, standardized floorplates, and cost-efficiency imperatives. Unlike the symbolic skyscrapers of North America or the expressive free-forms of the Middle East, the Korean model reflects a pragmatic synthesis between urban density, constructability, and affordability. Thus, the descriptive statistics presented here also illustrate how local policy and housing-market dynamics translate into a distinct architectural ideology, transforming efficiency from a quantitative index into a guiding design principle.

4.2. Key Structural Design Considerations: Structural Material and Structural Systems

Figure 9 shows a strong preference for concrete (75%, 46 buildings) over composite structures (25%, 15 buildings) in South Korean high-rises, reflecting its cost-effectiveness, availability, and structural reliability.

Concrete buildings, especially in residential developments (51 buildings), maintain consistent space efficiency (80–90%) due to optimized core systems. Office buildings (seven buildings) show greater efficiency variation (50–80%), influenced by larger service cores. Hotels (two buildings) and the mixed-use building have lower efficiency, prioritizing communal spaces.

Although composite structures represent only 25%, they achieve competitive space efficiency, exceeding 85% in some cases. Steel-concrete systems allow larger spans and flexible layouts, impacting efficiency based on function.

The findings confirm concrete's dominance in residential applications, while composite structures are strategically used for flexibility and structural performance, although with greater efficiency variation due to complex functional integration.

Despite the global prominence of steel in high-rise construction—particularly in Europe and the United States, where it is widely adopted for diagrid and other innovative structural systems—its application in South Korea remains negligible. The limited use of all-steel structures can be attributed to several factors: first, the dominance of reinforced concrete in the local construction industry, supported by well-established supply chains and contractor expertise; second, the cost-effectiveness and familiarity of concrete in residential developments, which constitute the majority of Korea's high-rises; and third, building codes and seismic considerations that favor the damping and fire-resistant properties of concrete and composite systems over pure steel frames. While steel offers clear advantages in terms of lightweight construction and long-span flexibility, especially for iconic or office-oriented towers, South Korea's high-rise paradigm reflects a pragmatic reliance on concrete and composite systems that balance efficiency, cost, and regulatory compliance.

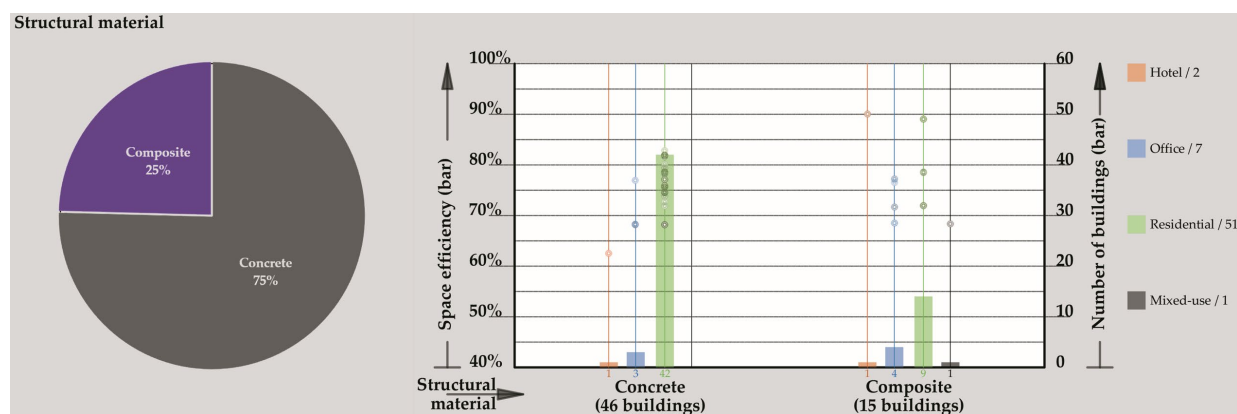


Figure 9. Material systems employed in the studied towers. Space efficiency is linked to each individual building, and bar graph data should be interpreted using the right axis.

Figure 10 highlights the dominance of outriggered frame systems (85%) in South Korean high-rises, followed by shear-walled frames (13%) and a single buttressed core structure (2%). This dominance is closely tied to building height: outriggered frame systems are predominantly used in towers exceeding 60 stories, where their ability to control drift and provide lateral stiffness is critical. By contrast, shear-walled frame systems are generally used for buildings with 30–50 stories, while buttressed core systems appear only in exceptional megatall cases. This correlation validates that structural system choices in Korea respond directly to height-driven performance requirements rather than stylistic preferences. Outriggered frames, mainly in residential towers (51 buildings), achieve high space efficiency (80–90%) due to structural stability and minimal core intrusions. Office buildings (seven buildings) using this system show greater efficiency variation (50–80%) due to larger service cores.

Shear-walled frames provide competitive efficiency in mid-rise residential buildings but limit flexibility in supertall towers. The single buttressed core reflects its specialized use in mega-tall structures, prioritizing lateral stability over space efficiency. This reduction in space efficiency occurs because the buttressed core system requires three massive shear-wall ‘buttresses’ radiating from the central hexagonal core, as exemplified by the Burj Khalifa. These structural wings are designed to resist enormous wind and gravity loads in megatall towers, ensuring superior lateral stability and torsional resistance. However, the very robustness of this configuration consumes a significant portion of each floor plate with thick structural walls and deep core zones. As a result, the net usable area available for functional spaces is considerably reduced compared to other systems, such as outriggered frame or tube configurations, which achieve lateral stiffness with less intrusion into the floor plan. These findings confirm a strong link between structural system selection and building function, with outriggered frames being the most efficient and adaptable for high-rise residential and mixed-use developments.

This link is explained by the fact that outriggered frame systems combine a reinforced concrete core with perimeter columns and outriggers, which together provide excellent lateral stiffness while maintaining relatively flexible floor layouts. In high-rise residential towers, this configuration allows for efficient apartment layouts around a compact core, while in mixed-use projects, it offers adaptability for integrating different functional zones such as retail, office, and residential within the same tower. Compared to pure shear-wall systems, which constrain flexibility, and tubular systems, which are costly and less common in Korea, outriggered frame systems strike an effective balance between structural performance, cost-efficiency, and spatial adaptability—explaining their dominance in the dataset.

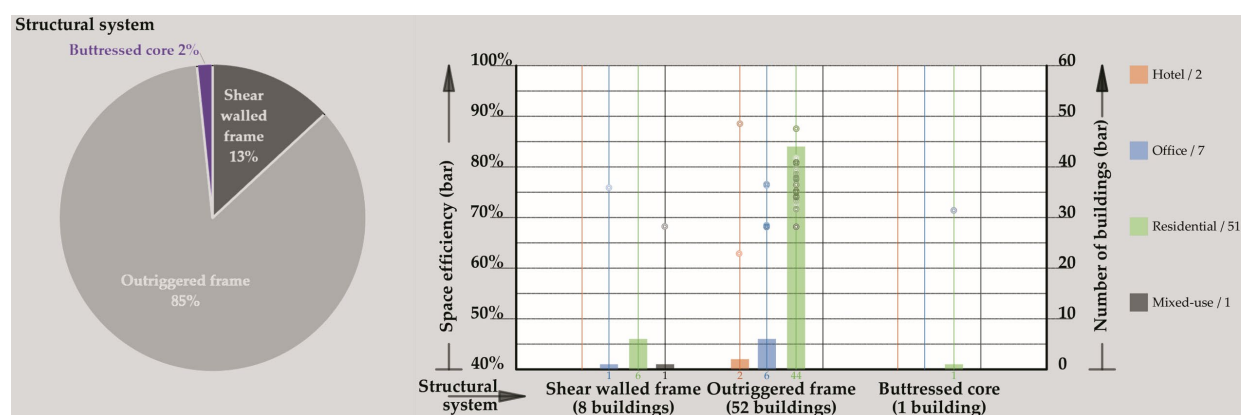


Figure 10. Structural systems applied in the analyzed towers. Space efficiency values are shown for each building; bar graph information should be read from the right axis only.

Figures 9 and 10 complement the textual discussion by visually mapping correlations between material preference, structural system, and spatial efficiency. When viewed together, they reveal the internal logic of Korea’s high-rise production—concrete construction consistently paired with outriggered frames to achieve optimal efficiency. These visuals clarify multi-variable relationships that would otherwise remain abstract, strengthening analytical comprehension without repeating descriptive detail.

Table 2 reveals distinct regional trends in structural materials and systems, shaped by urban density, construction economics, and engineering innovation.

Composite structures dominate in Asia (79%) and North America (39%), driven by seismic resilience and lightweight performance. In contrast, concrete is the primary material in the Middle East (70%), Shanghai (68%), and Singapore (68%), supporting cost-effective, large-scale construction. Steel use, while limited overall, is relatively higher in North America (6%) and Asia (3%), reflecting historical ties to early steel-framed skyscrapers, particularly in the U.S.

The outriggered frame system leads globally (85%), is favored in Asia (76%), the Middle East (44%), and North America (42%) for its effectiveness in distributing lateral loads in tall, mixed-use towers. Tube systems are notably present in Asia (17%), the Middle East (26%), and North America (16%), preferred in commercial projects for wind resistance and structural efficiency. Mega-core and mega-column systems support extreme-height designs, used notably in the Middle East (15%) and Asia (3%). Buttressed cores remain niche, found only in Asia (3%) and the Middle East (4%) for supertall towers demanding exceptional lateral stability.

Overall, concrete remains globally dominant, but composite systems are preferred in seismic or technologically advanced regions. Outrigger frames are the most widely adopted structural strategy, while tube and mega-frame systems reflect adaptations to height and zoning constraints. The limited use of buttressed cores highlights their specialized role in megatall engineering.

These variations underscore how local conditions—seismicity, cost, regulations, and height ambitions—drive the evolution of high-rise structural solutions worldwide.

Table 2. Comparative overview of structural materials and systems across global urban centers.

	Findings	Shanghai [76]	Singapore [87]	Asia [76]	The Middle East [77]	North America [78]
Structural Material	Concrete (75%)	Concrete (68%)	Concrete (68%)	Concrete (18%)	Concrete (70%)	Concrete (55%)
	Composite (25%)	Composite (30%)	Composite (30%)	Composite (79%)	Composite (30%)	Composite (39%)
		Steel (2%)	Steel (2%)	Steel (3%)		Steel (6%)
Structural System	Outrigger frame (85%)	Outrigger frame (23%)	Outrigger frame (17%)	Outrigger frame (76%)	Outrigger frame (44%)	Outrigger frame (42%)
	Shear-walled frame (13%)	Mega column (5%)	Mega column (5%)	Tube (17%)	Tube (26%)	Tube (16%)
	Buttressed core (2%)	Shear-trussed frame (70%)	Shear-trussed frame (2%)	Buttressed core (3%)	Buttressed core (4%)	Mega core (3%)
		Rigid Frame (2%)	Shear-walled frame (76%)	Mega column and core (3%)	Mega column and core (15%)	Shear-walled frame (39%)
				Shear frame (1%)	Shear frame (11%)	

The dominance of reinforced concrete and outriggered frame systems extends beyond practical construction preferences; it reflects a theoretical paradigm of structural rationalism. Within this paradigm, structural and material efficiency operate as architectural values in themselves, establishing a techno-economic logic that dictates spatial outcomes. The consistency of these systems across building types demonstrates the operation of what may be termed “systemic efficiency”, where design decisions converge toward optimal stability, manufacturability, and cost performance. Theoretically, this approach aligns with the notion of high-rise architecture as an engineering–architectural hybrid—an integrated organism that balances gravity, lateral forces, and usable area through interdependent subsystems. This convergence exemplifies how construction culture and regulatory uniformity consolidate around a shared epistemology of performance, privileging reliability and predictability over formal innovation. Therefore, the data do not merely record material choices but trace the evolution of a coherent technical ideology in which structure becomes both the medium and the message of architectural efficiency.

4.3. Relation of Space Efficiency and Key Design Considerations

This section presents a data-driven comparison of how core configurations, structural systems, and material choices impact space efficiency in South Korean high-rises versus global counterparts. Core and structural systems are assessed through measurable indicators—space efficiency ratios and core-to-GFA proportions—rather than as purely visual typologies.

South Korean towers average 76% space efficiency, aligning closely with North America (76%), the Middle East (75.5%), and Shanghai (75%) (see Table 3). Singapore leads with 80%

average and a 91% maximum, reflecting ultra-compact planning driven by land scarcity. In contrast, broader Asia shows the lowest average (67.5%), with some buildings dropping to 56%, likely due to seismic design demands and complex mixed-use functions.

Efficiency correlates strongly with function: Residential towers (84% of Korea's sample) achieve 80–90% efficiency, enabled by compact layouts and centralized cores. Office buildings (11%) show broader variation (50–80%) due to larger service cores and layout flexibility. Hotels and mixed-use towers trend slightly lower due to circulation-heavy communal and amenity spaces.

Core-to-GFA ratios further illustrate internal layout performance. South Korea averages 21%, matching North America and the Middle East (both 21%). Singapore's superior 17% average, with a minimum of 5%, demonstrates exceptional vertical and service space efficiency. Asia's higher ratio (30%) suggests structural conservatism tied to seismic and climatic constraints.

These findings highlight how regional design logics—shaped by density, regulation, and function—directly influence spatial efficiency and core strategy in high-rise architecture.

Table 3. Comparative overview of average space efficiency and average ratio of core to GFA across global urban centers.

	Findings	Shanghai [76]	Singapore [87]	Asia [76]	The Middle East [77]	North America [78]
Average space efficiency	76% (max. 88%, min. 63%)	75% (max. 93%, min. 52%)	80% (max. 91%, min. 68%)	67,50% (max. 82%, min. 56%)	75,50% (max. 84%, min. 63%)	76% (max. 84%, min. 62%)
Average ratio of core to GFA	21% (max. 31%, min. 11%)	23% (max. 33%, min. 5%)	17% (max. 32%, min. 5%)	30% (max. 38%, min. 14%)	21% (max. 36%, min. 11%)	21% (max. 31%, min. 13%)

Structural systems significantly affect space efficiency. In South Korea, outriggered frames—used in 85% of cases—support high efficiency in residential towers by offering strong lateral stability with minimal floorplate intrusion. Shear-walled frames, though less efficient in taller structures, provide compact solutions for mid-rise housing. The sole buttressed core example, while structurally ideal for extreme heights, compromises internal efficiency, limiting its use to landmark supertalls.

As shown in Figure 11, space efficiency emerges from the interplay of core typology, material choice, structural system, and form. The Korean model—central cores, prismatic forms, concrete construction, and outriggered frames—proves consistently effective. This integrated correlation highlights that structural and core strategies are not merely formal decisions but directly measurable determinants of spatial performance.

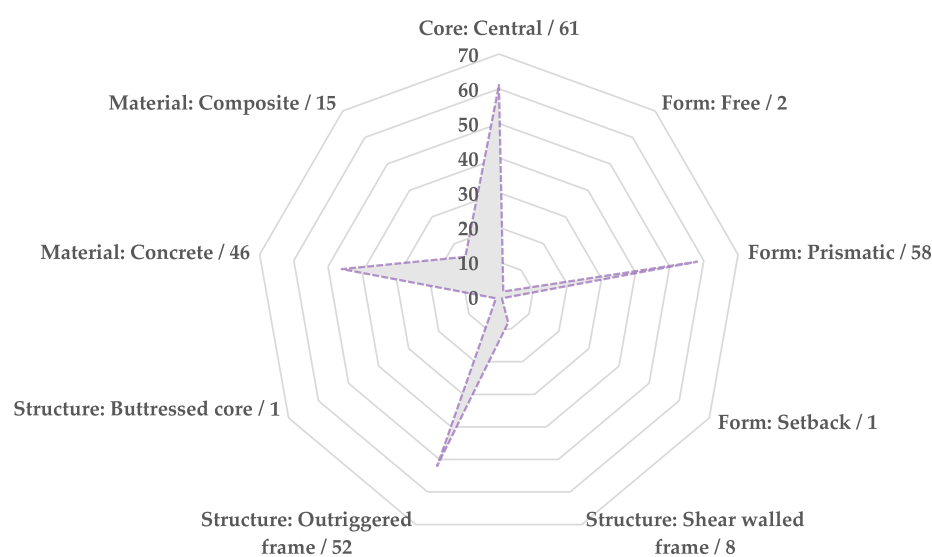


Figure 11. Core Types, Materials, Systems & Forms: Comparative Radar Chart. Radar chart correlating design parameters with space efficiency. Axes represent core, form, material, and system typologies; lines compare efficiency profiles.

Beyond comparative ratios, these relationships illuminate a broader theoretical framework for understanding tall building design as a self-regulating system. The strong correlation among form, core, structure, and material typologies reveals an underlying “techno-functional determinism”, wherein each design variable reinforces the others to achieve an optimized equilibrium between spatial performance and regulatory compliance. This configuration produces what can be called “rationalized vertical urbanism”—a mode of architectural production guided by measurable efficiency rather than symbolic representation. The homogeneity of South Korean high-rises, often critiqued as monotonous, can thus be reframed as the expression of systemic optimization, where architectural diversity is replaced by performance consistency. From a theoretical standpoint, this system-oriented interpretation situates Korean high-rises within the discourse of architectural structuralism and systems theory, suggesting that tall buildings operate not as isolated objects but as dynamic, rule-based networks linking social, economic, and technical parameters. Consequently, the empirical evidence presented here serves as the foundation for the integrative theoretical model developed in Section 4.4.

Figure 11 functions as an integrative synthesis rather than a repetition of prior charts. By uniting architectural, structural, and material parameters within a single efficiency framework, it visualizes the relational logic underpinning the study’s theoretical argument. The figure translates complex interdependencies—core configuration, form, material, and system—into an interpretable pattern of proportional efficiencies, reinforcing the conceptual transition toward the integrative model proposed in Section 4.4.

The data affirms a strong link between design choices and spatial performance. Buildings featuring prismatic forms, central cores, and concrete structures consistently exhibit the highest space efficiency. This underscores that core and structural systems are strategic, not merely aesthetic, decisions with measurable functional outcomes. The study’s quantitative benchmarks provide a replicable framework for cross-regional and typological evaluation, offering an analytical contribution to the global discourse on high-rise design efficiency.

4.4. Toward a Theoretical Framework for High-rise Typologies

The comparative evidence presented in Tables 1–3 not only provides descriptive insights but also offers the foundation for constructing a preliminary theoretical framework to evaluate high-rise building typologies. This framework links three major domains: (i) architectural parameters (function, core type, form), (ii) structural strategies (system and material), and (iii) spatial outcomes (net-to-gross floor area efficiency and core-to-GFA ratios). Together, these domains create an integrated matrix where changes in one dimension reverberate across others.

4.4.1. Interdependencies among Parameters

Findings suggest clear interdependencies.

- **Function and Core.** Function strongly conditions the core configuration and size. Residential towers in Korea, with compact and repetitive unit layouts, consistently achieve higher spatial efficiency (80–90%) through centralized cores, whereas office towers require enlarged service cores and vertical circulation, lowering efficiency to as little as 50%. Hotel and mixed-use towers further reduce efficiency due to extensive communal and amenity spaces. This dependency aligns with earlier studies indicating that programmatic requirements are primary determinants of spatial yield in tall buildings [28].
- **Form and Structural System.** Form interacts with the structural system choice. Prismatic forms, which dominate Korean cases (95%), allow straightforward adoption of outrigger frames and reinforced concrete, ensuring predictable load paths and cost-effective construction. In contrast, free-form or setback geometries require composite or steel–concrete hybrid systems, leading to increased structural complexity, larger material volumes, and efficiency losses. This is consistent with research on aerodynamic and sculptural forms, where expressive geometries often entail trade-offs with usable space [33].
- **Structural System and Efficiency.** Structural system selection mediates spatial performance directly. Outriggered frame systems balance lateral stability and usable area, enabling column-free interiors that reinforce efficiency. Shear-walled frame systems, while advantageous in seismic resilience, reduce spatial adaptability and increase service core ratios. The rare buttressed core configuration, though structurally optimal for megatall towers, demonstrates efficiency drawbacks that make it unsuitable for mid-rise or

residential applications. Such trade-offs underscore the importance of system–function matching in high-rise typology [30].

- **Material Use and Adaptability.** Material choice mediates both cost and adaptability. Concrete dominates for its cost-effectiveness and local availability, while composite and steel systems allow larger spans and flexibility but are resource-intensive and less favored in the Korean market context.

4.4.2. Toward a Generalizable Framework

These interrelations point to a network-based understanding of high-rise design, where no single parameter operates in isolation. Instead, efficiency emerges from the convergence of architectural intent, structural pragmatism, and material logic. Based on the Korean dataset, the following dependency rules can be proposed as a framework for comparative studies:

- **Function → Core and Efficiency:** Residential → compact central core → high efficiency; Office/Hotel → larger cores → lower efficiency.
- **Form → Structural System:** Prismatic → concrete + outrigger → efficiency optimized; Free-form/Setback → composite + hybrid systems → efficiency trade-off.
- **Structural System → Efficiency Outcome:** Outrigger → stable and efficient; Shear-wall → resilient but less efficient; Buttressed core → viable only at extreme heights.
- **Material Use → Adaptability:** Concrete → cost-effective but conservative; Composite/steel → flexible, higher spans, but resource-intensive.

By systematizing these dependencies, this study contributes beyond descriptive statistics toward an analytical framework that is both predictive and comparative. For example, given a design input of residential + central core + prismatic form + outrigger system, one can anticipate a space efficiency range of ~80–90%, whereas office + free-form + composite structure may yield significantly lower ratios.

4.4.3. Implications for Global Application

The proposed framework not only contextualizes Korean high-rise practices but also provides a replicable model for other regions. Its predictive value allows benchmarking of new projects against established patterns, facilitating early-stage decision-making in both design and policy contexts. Moreover, this framework offers a starting point for future work that could incorporate additional layers—such as environmental performance, cultural symbolism, or regulatory constraints—thus extending typological theory beyond efficiency metrics. In this way, the Korean dataset becomes a laboratory for theorizing the interdependencies that structure high-rise design globally, while opening pathways for comparative research across different urban contexts.

5. Discussion

The comparative analysis of South Korea's high-rise architecture reveals a context-specific paradigm shaped by spatial efficiency, structural pragmatism, and cost-conscious material use. These strategies respond directly to urban constraints—dense populations, limited land, and housing demand. As evidenced across the dataset, Korean towers consistently adopt centralized cores, prismatic forms, and reinforced concrete, supporting rapid, modular construction and high net floor area yields. However, while effective domestically, their broader applicability requires adaptation to environmental, cultural, and regulatory differences [88–94].

Functionally, Korea's 84% residential share sets it apart from office-driven Shanghai and Asia, and mixed-use-oriented Middle East and North America. This mono-functionality reflects urgent housing demands and zoning norms that deprioritize integration. The result is highly efficient, single-use layouts—efficient but less adaptable to mixed-use planning models like those in Singapore or the UAE, where land use mixing is core to urban strategy.

Structurally, the universal use of central cores (100%) in Korea supports internal efficiency and load distribution, aligning with Asia (99%) and North America (90%). However, peripheral or external cores, seen in Singapore and Shanghai, offer greater façade flexibility and are better suited to open-plan or atrium-based layouts—suggesting Korea's core strategy may be limiting in more expressive or flexible urban design contexts.

The prevalence of mono-functional residential towers in South Korea reflects deeper socio-economic drivers rather than being a mere statistical fact. Regulatory frameworks have

consistently prioritized large-scale housing provision, while developers have responded to strong demand for cost-efficient units in high-density contexts. Similarly, the dominance of reinforced concrete structures arises not only from cost advantages but also from construction culture and supply-chain familiarity, which reinforce conservative material choices. Prismatic forms, meanwhile, have been favored because their geometric regularity allows standardized floor plates and efficient use of core and structural systems, thereby balancing speed, cost, and functionality. Together, these patterns illustrate that Korean high-rise development is shaped by pragmatic economic and policy logics rather than expressive architectural experimentation, offering insights into how national urban strategies directly translate into building typologies.

Beyond descriptive comparison, the observed patterns reveal deeper architectural and urban implications. The dominance of residential towers in South Korea reflects the country's policy-driven focus on maximizing urban density and housing supply, with space efficiency prioritized over architectural experimentation. This contrasts with North America and the Middle East, where tall buildings often serve as iconic urban symbols or speculative commercial investments, leading to greater diversity in form, function, and structural innovation.

The reliance on prismatic geometries and concrete structural systems in Korea underscores a pragmatic culture of cost efficiency, standardization, and regulatory compliance. While this strategy ensures reliable delivery of a large housing stock, it also limits opportunities for spatial diversity, mixed-use integration, and expressive urban skylines. In contrast, regions adopting hybrid structural systems or free-form geometries pursue different priorities—whether enhancing global city branding, promoting mixed-use vibrancy, or testing new structural-material synergies.

These differences matter because tall building typologies both reflect and shape urban life: they influence not only skyline aesthetics but also patterns of mobility, energy use, and social interaction. Situating the Korean dataset within this global discourse helps demonstrate how architectural decisions at the building scale are intertwined with broader urban strategies, policies, and cultural values.

Form-wise, Korea's reliance on prismatic geometries (95%) favors modularity and structural clarity but contrasts sharply with the iconic, sculptural forms favored in Dubai or New York, where skyline branding and aerodynamic design are prioritized. Minimal use of setback (2%) and free-form (3%) configurations further reinforces a conservative design ethos focused on efficiency over identity or environmental responsiveness.

Korea also shows limited structural diversity, with outriggered frame systems used in 85% of cases. While effective for tall, slender towers, this system may underperform in seismic or high-wind zones, where tube, diagrid, or hybrid systems are more prevalent. The lone example of a buttressed core suggests a focus on mid- to high-rise practicality, rather than iconic mega-tall ambitions common in other regions.

In material terms, Korea's heavy use of reinforced concrete (75%) underscores economic and logistical efficiency, despite concrete's limitations in seismic resilience and structural flexibility. In contrast, composite and steel systems, more common in North America and Asia, support higher performance in challenging contexts. Yet, Korea still matches global leaders in space efficiency (76%), validating the effectiveness of its planning logic, even as it reveals a cautious stance toward material innovation.

Overall, Korea's high-rise model is highly optimized for local needs, but its exportability is limited. Seismic risk, climatic pressures, and cultural aesthetics in regions like Japan, California, or the Gulf demand alternative systems, from base-isolated structures to aerodynamically modeled forms. While Korea offers a strong example of rationalized high-rise development, true global adaptability requires broader flexibility in core design, structural strategy, and formal expression.

Beyond these architectural and technical considerations, the findings also carry implications for sustainability, social relevance, and policy. The efficiency-driven reliance on reinforced concrete and standardized forms reduces experimentation with low-carbon or hybrid materials, raising questions about long-term environmental performance. Functionally, the predominance of residential towers reflects socio-economic priorities in housing supply but limits mixed-use vibrancy, with consequences for urban livability. At the policy level, the dominance of regulation-driven typologies illustrates how planning frameworks shape tall building outcomes, highlighting the need for strategies that balance efficiency with innovation to meet future sustainability and urban resilience goals.

Beyond the architectural and technical dimensions, this study highlights that spatial efficiency in South Korea's high-rise architecture operates as both a quantitative performance indicator and a socio-cultural construct. Efficiency-driven design solutions—centralized cores, prismatic geometries, and reinforced-concrete systems—reflect not only engineering optimization but also deeper socio-economic imperatives. The chronic housing shortage, high urban density, and policy emphasis on affordability have collectively produced a built environment where spatial efficiency equates to social responsibility and economic rationality. Developers prioritize floor area yield and constructability because these directly affect unit affordability and project approval under state-regulated frameworks. Culturally, the preference for standardized, compact, and repetitive layouts resonates with collective ideals of order, predictability, and stability—values that align with South Korea's broader developmental ethos. Consequently, what appears as architectural pragmatism is in fact the spatial manifestation of intertwined economic pressures, policy constraints, and cultural norms. Interpreting spatial efficiency through this socio-economic lens clarifies that the Korean high-rise model represents not just technical optimization but an architectural expression of national priorities balancing density, affordability, and social cohesion.

6. Conclusion

This study presents a data-driven comparative analysis of 61 high-rise buildings across six South Korean cities, revealing a unified national design approach centered on efficiency, standardization, and cost-effectiveness. Korean towers overwhelmingly adopt central cores (100%), prismatic forms (95%), reinforced concrete (75%), and outriggered frame systems (85%), resulting in high average spatial efficiency (76%)—comparable to benchmarks in North America and the Middle East. These strategies are particularly well-suited to Korea's residential-focused urban fabric (84% of the sample).

Findings indicate that Korean high-rise design is primarily shaped by functional, regulatory, and economic imperatives, emphasizing practicality over expressive or experimental form-making. In contrast to North America and the Middle East, Korea underutilizes mixed-use programs, sculptural geometries, and composite or steel systems, reflecting a pragmatic and cost-conscious paradigm tailored to its dense urban and policy context. This pattern underscores how efficiency-oriented design priorities have evolved into a coherent architectural logic—balancing constructability, performance, and regulatory alignment.

However, this study also has certain limitations. The dataset excludes under-construction and experimental projects, which may exhibit emerging typologies or alternative structural approaches. In addition, the research relies on static indicators such as NFA-to-GFA ratios, without integrating simulation-based analyses (e.g., wind, seismic, or thermal performance) that could further substantiate the spatial and structural findings under dynamic conditions.

Future research should build on this foundation by combining empirical spatial data with advanced performance simulations and mixed-method evaluations. Comparative studies encompassing other regions and mixed-use typologies would provide further insight into how efficiency-based models adapt to differing socio-economic and environmental contexts. Such extensions will strengthen the generalizability of the present framework and deepen understanding of the evolving design logic of high-rise architecture.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability

Data supporting this study are included within the article.

Author Contributions

Conceptualization: H.E.I.; Formal analysis: K.O.A., A.J., & Ö.N.A.; Investigation: K.O.A., A.J., Ö.N.A., & G.G.A.; Methodology: Ö.N.A., & H.E.I.; Software: K.O.A., A.J., Ö.N.A., & G.G.A.; Supervision: H.E.I.; Writing – original draft: K.O.A., A.J., Ö.N.A., & G.G.A.; Writing – review & editing: K.O.A., A.J., Ö.N.A., & G.G.A.

Conflicts of Interest

The authors have no conflict of interest to declare.

References

1. Yun, J. (2024). Luxury of Traditional Architecture: Emergence of Hanoks as Luxury Housing. *Buildings*, *14*(10), 3129. <https://doi.org/10.3390/buildings14103129>
2. Kim, Y.-J. (2021). Reconstructing Pure Land Buddhist Architecture in Ancient East Asia. *Religions*, *12*(9), 764. <https://doi.org/10.3390/rel12090764>
3. Woo, K. S., & Suh, J. H. (2017). Urban landscape image study by text mining and factor analysis—Focused on Lotte World Tower (in Korean). *Journal of the Korean Institute of Landscape Architecture*, *45*(4), 104–117. <https://doi.org/10.9715/KILA.2017.45.4.104>
4. Ilgin, H. E. (2021). Space Efficiency in Contemporary Supertall Office Buildings. *Journal of Architectural Engineering*, *27*(3). [https://doi.org/10.1061/\(ASCE\)AE.1943-5568.0000486](https://doi.org/10.1061/(ASCE)AE.1943-5568.0000486)
5. Du, P., Little, G., & Romero, E. (2025). Balancing Construction Costs and Environmental and Social Performances in High-Rise Urban Development: A Generative Urban Design Approach. *Buildings*, *15*(5), 661. <https://doi.org/10.3390/buildings15050661>
6. Armstrong, C. K. (2009). The destruction and reconstruction of North Korea, 1950–1960. *Asia-Pacific Journal*, *7*, 3460.
7. Paszkowski, Z. W., & Czyńska, K. (2025). The Mixed-Use High-Rise Building as a Contemporary Design Challenge: Hanza Tower in Szczecin, Poland. *Housing Environment/Środowisko Mieszkaniowe*, *50*(1), 18–36. <https://doi.org/10.2478/he-2025-0003>
8. Ilgin, H. E., Karjalainen, M., & Koponen, O.-P. (2021). Dovetailed massive wood board elements for multi-story buildings. In *LivenARCH VII: livable environments & architecture: Other architect/ure(s) proceedings* (Vol. 1, pp. 47–60). Karadeniz Teknik Üniversitesi.
9. Häkkinen, L., Ilgin, H. E., & Karjalainen, M. (2022). The Current State of the Finnish Cottage Phenomenon: Perspectives of Experts. *Buildings*, *12*(3), 260. <https://doi.org/10.3390/buildings12030260>
10. Tuure, A., Hirvilampi, T., Ilgin, H. E., & Karjalainen, M. (2024). Finnish mid-rise timber apartment buildings: Architectural, structural, and constructional features. *Architectural Research in Finland*, *8*(1), 88–119. <https://doi.org/10.37457/arf.146875>
11. Karjalainen, M., Ilgin, H. E., & Somelar, D. (2021). Wooden extra stories in concrete block of flats in Finland as an ecologically sensitive engineering solution. In *Ecological Engineering—Addressing Climate Challenges and Risks*. InTech Open. <https://doi.org/10.5772/intechopen.101171>
12. Karjalainen, M., & Ilgin, H. E. (2021). A Statistical Study on Multi-story Timber Residential Buildings (1995–2020) in Finland. In *LivenARCH VII: livable environments & architecture: Other architect/ure(s) proceedings* (Vol. 1, pp. 82–94). Karadeniz Teknik Üniversitesi.
13. Seo, J.-K. (2016). Housing policy and urban sustainable development: evaluating the process of high-rise apartment development in Korea. *Urban Policy and Research*, *34*(4), 330–342. <https://doi.org/10.1080/08111146.2015.1118373>
14. Taeyoon, K., & Kilhun, L. (2022). Planning and construction of the post-liberation capital city of Seoul (1945–1950): a focus on planning and the removal of firebreaks. *Journal of Asian Architecture and Building Engineering*, *21*(6), 2277–2284. <https://doi.org/10.1080/13467581.2021.1976191>
15. Park, J.-I. (2025). The road to sustainable industrial land development: location patterns, morphological characteristics, and policy implications of South Korean urban high-tech industrial parks. *International Journal of Urban Sciences*, *29*(2), 479–502. <https://doi.org/10.1080/12265934.2024.2435844>
16. Kim, Y. J., Kim, M. J., & Jun, H. J. (2025). Revitalizing old low-rise residential environments by focusing on communities: case studies in Seoul, Korea. *Archnet-IJAR: International Journal of Architectural Research*. <https://doi.org/10.1108/ARCH-08-2024-0373>
17. Son, J.-M., Eum, J.-H., Kim, D.-P., & Kwon, J. (2018). Management Strategies of Thermal Environment in Urban Area Using the Cooling Function of the Mountains: A Case Study of the Honam Jeongmaek Areas in South Korea. *Sustainability*, *10*(12), 4691. <https://doi.org/10.3390/su10124691>
18. Lee, J. M., & Lee, H. (2025). The effect of building height regulation in Seoul. *International Journal of Urban Sciences*, *29*(3), 604–626. <https://doi.org/10.1080/12265934.2024.2382703>
19. Lee, M. S., & Lee, S. J. (2023). Reconfiguration of Korea Highrise Residential Spaces in Response to Pandemic. *International Journal of High-Rise Buildings*, *12*(4), 351–362. <https://doi.org/10.21022/IJHRB.2023.12.4.351>
20. Remizov, A., Memon, S. A., & Kim, J. R. (2023). Climate Zoning for Buildings: From Basic to Advanced Methods—A Review of the Scientific Literature. *Buildings*, *13*(3), 694. <https://doi.org/10.3390/buildings13030694>
21. Jeong, S., Jeon, S., Ban, Y., & Park, J. (2021). Thematic Trends in the Research on Green Urbanism. *LHI Journal of Land, Housing, and Urban Affairs*, *12*(2), 61–78. <https://doi.org/10.5804/LHIJ.2021.12.2.61>
22. Li, Y. (2025). A Study of Eco-city Construction and Design in Japan from the Perspective of Urban Ecology. *Mediterranean Archaeology and Archaeometry*, *25*(2), 1665.
23. Jun, N. I., & Yang, S. H. (2012). The Influence of Early Government-sponsored Housing on the Modernization of Korean Housing: From Post-Korean War to Late 1960s. *International Journal of Human Ecology*, *13*(1), 147–157. <https://doi.org/10.6115/ijhe.2012.13.1.147>

24. Jung, Y., & Cinn, E. (2020). Conflicting ideals and realities: the architecture of South Korea's first high-rise housing complex. *The Journal of Architecture*, 25(6), 736–758. <https://doi.org/10.1080/13602365.2020.1802613>
25. Kim, G. D., & Lee, J. H. (2016). Key technologies for super tall building construction: Lotte world tower. *International Journal of High-Rise Buildings*, 5(3), 205–211. <https://doi.org/10.21022/IJHRB.2016.5.3.205>
26. Kim, J., Jung, Y., Kim, J., & Kim, T. (2015). Challenges and Opportunities for the Structural Design of the 123-Story Jamsil Lotte World Tower. In *Proceedings of the CTBUH 2015 New York International Conference* (pp. 502–509). Council on Tall Buildings and Urban Habitat.
27. Nam, S., & Lee, S.-O. (2023). Urban regeneration in Seoul: alternative urbanism or the resilience of neoliberal urbanism? *International Journal of Urban and Regional Research*, 47(4), 601–623. <https://doi.org/10.1111/1468-2427.13180>
28. Lindberg, T., Kaasalainen, T., Moisio, M., Mäkinen, A., Hedman, M., & Vinha, J. (2020). Potential of space zoning for energy efficiency through utilization efficiency. *Advances in Building Energy Research*, 14(1), 19–40. <https://doi.org/10.1080/17512549.2018.1488619>
29. Mobaraki, A., & Oktay Vehbi, B. (2022). A Conceptual Model for Assessing the Relationship between Urban Morphology and Sustainable Urban Form. *Sustainability*, 14(5), 2884. <https://doi.org/10.3390/su14052884>
30. Ho, G. W. (2016). The evolution of outrigger system in tall buildings. *International Journal of High-Rise Buildings*, 5(1), 21–30.
31. Sikumbang, I. H., & Yola, L. (2023). The Transformation of the Marina Bay Sand Area: The History of Managing the Energy Balance of Singapore. *International Review of Humanities Studies*, 8(2), 3. <https://doi.org/10.7454/irhs.v8i2.1109>
32. Xie, J. (2014). Aerodynamic optimization of super-tall buildings and its effectiveness assessment. *Journal of Wind Engineering and Industrial Aerodynamics*, 130, 88–98. <https://doi.org/10.1016/j.jweia.2014.04.004>
33. Ilgin, H. E., & Günel, M. H. (2021). Contemporary Trends in Supertall Building Form: Aerodynamic Design Considerations. In *LiveARCH VII: livable environments & architecture: Other architect/ure(s) proceedings* (Vol. 1, pp. 61–81). Karadeniz Teknik Üniversitesi.
34. Fang, T., Gong, J., Dong, X., Li, Y., Cui, W., & Feng, Y. (2025). Aerodynamic characteristics and structural effects of suspending scaffolds for super high-rise building construction. *Journal of Building Engineering*, 107, 112718. <https://doi.org/10.1016/j.jobe.2025.112718>
35. Ilgin, H. E. (2022). Use of aerodynamically favorable tapered form in contemporary supertall buildings. *Journal of Design for Resilience in Architecture and Planning*, 3(2), 183–196. <https://doi.org/10.47818/DRArch.2022.v3i2052>
36. Ilgin, H. E. (2023). Examining space efficiency in supertall towers through an analysis of 135 case studies. *International Journal of Architectural Engineering Technology*, 10, 140–157. <https://doi.org/10.15377/2409-9821.2023.10.10>
37. Dizdaroglu, D. (2022). Developing design criteria for sustainable urban parks. *Journal of Contemporary Urban Affairs*, 6(1), 69–81. <https://doi.org/10.25034/ijcua.2022.v6n1-7>
38. Ilgin, H. E. (2021). Space Efficiency in Contemporary Supertall Residential Buildings. *Architecture*, 1(1), 25–37. <https://doi.org/10.3390/architecture1010004>
39. Ilgin, H. E. (2023). A study on interrelations of structural systems and main planning considerations in contemporary supertall buildings. *International Journal of Building Pathology and Adaptation*, 41(6), 1–25. <https://doi.org/10.1108/IJBPA-12-2021-0172>
40. Ipsen, K. L., Pizzol, M., Birkved, M., & Amor, B. (2024). Environmental performance of eco-design strategies applied to the building sector. *Journal of Industrial Ecology*, 28(3), 556–572. <https://doi.org/10.1111/jiec.13465>
41. Ali, M. M., & Moon, K. S. (2007). Structural developments in tall buildings: Current trends and future prospects. *Architectural Science Review*, 50(3), 205–223. <https://doi.org/10.3763/asre.2007.5027>
42. Biswas, M. H. A., Dey, P. R., Islam, M. S., & Mandal, S. (2022). Mathematical model applied to green building concept for sustainable cities under climate change. *Journal of Contemporary Urban Affairs*, 6(1), 36–50. <https://doi.org/10.25034/ijcua.2022.v6n1-4>
43. Cho, J., Jang, A., Kim, M., Oh, I., Do, S. L., & Park, B. (2024). Evaluating Climate Change's Impact on Outdoor Conditions for Building Cooling and Heating Design: A Focus on Korea's Last Decade. *Journal of the Architectural Institute of Korea*, 40(11), 199–210.
44. Kim, S., Yoon, E. J., & An, S. H. (2020). Landscaping Trees under the Impacts of Climate Changes: Construction Professionals' Perceptions in the Field of Landscape Architecture in South Korea. *International Review for Spatial Planning and Sustainable Development*, 8(1), 94–106. https://doi.org/10.14246/irspsd.8.1_94
45. Kim, K. H., & Pauleit, S. (2007). Landscape character, biodiversity and land use planning: The case of Kwangju City Region, South Korea. *Land Use Policy*, 24(1), 264–274. <https://doi.org/10.1016/j.landusepol.2005.12.001>
46. Lee, S., & Bae, D. H. (2012). Local effects of climate change over South Korea with a high-resolution climate scenario. *Climate Research*, 54(1), 85–93. <https://doi.org/10.3354/cr01109>
47. Kim, J. T., & Yu, C. W. F. (2018). Sustainable development and requirements for energy efficiency in buildings—the Korean perspectives. *Indoor and Built Environment*, 27(6), 734–751. <https://doi.org/10.1177/1420326X18764618>

48. Lee, H. K. (2019). The problematic past and difficult heritage: The Japanese colonial occupation of Korea and its architectural legacies. In *'Difficult Heritage' in Nation Building: South Korea and Post-Conflict Japanese Colonial Occupation Architecture* (pp. 1–43). Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-66338-8_1
49. Mukherjee, M., Abhinay, K., Rahman, M. M., Yangdhen, S., Sen, S., Adhikari, B. R., et al. (2023). Extent and evaluation of critical infrastructure, the status of resilience and its future dimensions in South Asia. *Progress in Disaster Science*, 17, 100275. <https://doi.org/10.1016/j.pdisas.2023.100275>
50. Kim, H., Choi, H., Kang, H., An, J., Yeom, S., & Hong, T. (2021). A systematic review of the smart energy conservation system: From smart homes to sustainable smart cities. *Renewable and Sustainable Energy Reviews*, 140, 110755. <https://doi.org/10.1016/j.rser.2021.110755>
51. Kwon, H.-a., & Kim, S. (2021). The Functions of Housing in Response to Changed Lifestyles in Korean Residential Spaces: A Comparative Analysis of the Cases in Lifestyle and Architectural Magazines. *Sustainability*, 13(21), 12079. <https://doi.org/10.3390/su132112079>
52. Muhy Al-Din, S. S., Ahmad Nia, H., & Rahbarianyazd, R. (2023). Enhancing Sustainability in Building Design: Hybrid Approaches for Evaluating the Impact of Building Orientation on Thermal Comfort in Semi-Arid Climates. *Sustainability*, 15(20), 15180. <https://doi.org/10.3390/su152015180>
53. Kim, J. K. (2008). A Study on the Improvement and Environment-friendly Interior Space Planning of High-rise Residences in Korea - focused on the case analysis by environment-friendly architectural certification. *Korean Institute of Interior Design Journal*, 17(3), 23–33.
54. Singh, R. P., & Niglio, O. (2024). Asian Rural Cultural Landscapes: Culture-Nature Interfaces and Sustainability. *EdA, Esempi di Architettura, International Journal of Architecture and Engineering*, 11, 18–35.
55. Cattaneo, T., Giorgi, E., Ni, M., & Manzoni, G. D. (2016). Sustainable Development of Rural Areas in the EU and China: A Common Strategy for Architectural Design, Research Practice and Decision-Making. *Buildings*, 6(4), 42. <https://doi.org/10.3390/buildings6040042>
56. Hyun, J. (2021). Brokering science, blaming culture: The US–South Korea ecological survey in the Demilitarized Zone, 1963–8. *History of Science*, 59(3), 315–343. <https://doi.org/10.1177/0073275320974209>
57. Yun, C. B., Lee, J. J., & Koo, K. Y. (2011). Smart structure technologies for civil infrastructures in Korea: recent research and applications. *Structure and Infrastructure Engineering*, 7(9), 673–688. <https://doi.org/10.1080/15732470902720109>
58. Papadakis, N., & Katsaprakakis, D. A. (2023). A Review of Energy Efficiency Interventions in Public Buildings. *Energies*, 16(17), 6329. <https://doi.org/10.3390/en16176329>
59. Yuen, B., Yeh, A., Appold, S. J., Earl, G., Ting, J., & Kurnianingrum Kwee, L. (2006). High-rise living in Singapore public housing. *Urban Studies*, 43(3), 583–600. <https://doi.org/10.1080/00420980500533133>
60. Kim, J., & Ahn, Y. J. (2025). Landscape, power, and speculative urbanism in Songdo, South Korea. *Landscape Research*, 1–15. <https://doi.org/10.1080/01426397.2025.2551276>
61. Xue, C. Q., & Li, Y. (2008). Importing American architecture to China: the practice of John Portman & Associates in Shanghai. *The Journal of Architecture*, 13(3), 317–333. <https://doi.org/10.1080/13602360802214786>
62. Roche Cárcel, J. A. (2021). The spatialization of time and history in the skyscrapers of the twenty-first century in Shanghai. *City, Territory and Architecture*, 8, 7. <https://doi.org/10.1186/s40410-021-00136-z>
63. Kim, K. H., Chae, C. U., & Cho, D. (2022). Development of an assessment method for energy performance of residential buildings using G-SEED in South Korea. *Journal of Asian Architecture and Building Engineering*, 21(1), 133–144. <https://doi.org/10.1080/13467581.2020.1838286>
64. Saadatjoo, P., & Ahmad Nia, H. (2024). Evaluating Sustainable Approaches for Enhancing Building Resilience in Response to Climate Change (Case study: Tehran City). *Journal of Salutogenic Architecture*, 3(1), 135–149. https://doi.org/10.38027/jsalutogenic_vol3no1_11
65. Lacidogna, G., Scaramozzino, D., & Carpinteri, A. (2020). Influence of the geometrical shape on the structural behavior of diagrid tall buildings under lateral and torque actions. *Developments in the Built Environment*, 2, 100009. <https://doi.org/10.1016/j.dibe.2020.100009>
66. Lacidogna, G., Nitti, G., Scaramozzino, D., & Carpinteri, A. (2020). Diagrid systems coupled with closed-and open-section shear walls: Optimization of geometrical characteristics in tall buildings. *Procedia Manufacturing*, 44, 402–409. <https://doi.org/10.1016/j.promfg.2020.02.277>
67. Lacidogna, G., Nitti, G., Scaramozzino, D., & Carpinteri, A. (2021). Diagrid system coupled with shear walls: Analytical investigation on the dynamical response in tall buildings. In *Proceedings of the 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN)* (pp. 1793–802). Institute of Research and Development for Computational Methods in Engineering Sciences (ICMES).
68. Cucuzza, R., Aloisio, A., Rad, M. M., & Domaneschi, M. (2024). Constructability-based design approach for steel structures: From truss beams to real-world inspired industrial buildings. *Automation in Construction*, 166, 105630. <https://doi.org/10.1016/j.autcon.2024.105630>
69. Cucuzza, R., Rad, M. M., Domaneschi, M., & Marano, G. C. (2024). Sustainable and cost-effective optimal design of steel structures by minimizing cutting trim losses. *Automation in Construction*, 167, 105724. <https://doi.org/10.1016/j.autcon.2024.105724>
70. Di Bari, R., Cucuzza, R., Domaneschi, M., & Mitoulis, S. A. (2025). Enhancing Sustainability and Resilience Against Natural Hazard of the Built Environment—State of the Art and Development of a Novel Framework. *Sustainable Development*. <https://doi.org/10.1002/sd.70150>
71. Council on Tall Buildings and Urban Habitat, Illinois Institute of Technology (CTBUH). (n.d.). *Introducing Council on Vertical Urbanism*. <https://www.ctbuh.org> (accessed 26 October 2025).

72. Taherdoost, H. (2022). What are different research approaches? Comprehensive review of qualitative, quantitative, and mixed method research, their applications, types, and limitations. *Journal of Management Science & Engineering Research*, 5(1), 53–63. <https://doi.org/10.30564/jmsr.v5i1.4538>
73. Drozd, M., Appert, M., & Harris, A. (2018). High-rise urbanism in contemporary Europe. *Built Environment*, 43(4), 469–480.
74. Brown, S. E., & White, T. J. (2023). Inquiry Stories: A Systematic Review of Qualitative Research Design. *Qualitative Research Review Letter*, 1(1), 40–47.
75. Kim, H. I., & Elnimeiri, M. (2004). Space efficiency in multi-use tall building. In *Proceedings of the Tall Buildings in Historical Cities-Culture and Technology for Sustainable Cities, Seoul, Republic of Korea* (pp. 10–13). Council on Tall Buildings and Urban Habitat.
76. Ilgin, H. E. (2023). An analysis of space efficiency in Asian supertall towers. *International Journal of Building Pathology and Adaptation*, 41(6), 237–253. <https://doi.org/10.1108/IJBPA-06-2023-0082>
77. Ilgin, H. E. (2025). Examination of spatial efficiency in super-tall towers within the Middle Eastern context. *Open House International*, 50(1), 191–208. <https://doi.org/10.1108/OHI-11-2023-0263>
78. Ilgin, H. E., & Aslantamer, Ö. N. (2024). Space Efficiency in North American Skyscrapers. *Buildings*, 14(8), 2382. <https://doi.org/10.3390/buildings14082382>
79. Taghizadeh, K., & Seyedinnor, S. (2013). Super-tall buildings forms based on structural concepts and energy conservation principles. *Architecture Research*, 3, 13–19. <https://doi.org/10.5923/j.arch.20130302.01>
80. Azizi, M., Talatahari, S., Basiri, M., & Shishehgarkhaneh, M. B. (2022). Optimal design of low-and high-rise building structures by Tribe-Harmony Search algorithm. *Decision Analytics Journal*, 3, 100067. <https://doi.org/10.1016/j.dajour.2022.100067>
81. Lee, S. (2021). A Study on the Trends for Expression in Korean Contemporary Architectural Facade Design: Focusing on Large Buildings in the City Center. *Buildings*, 11(7), 274. <https://doi.org/10.3390/buildings11070274>
82. Nam, H. J., & Shim, J. H. (2016). An analysis of the change in space efficiency based on various tall building corner shapes and lease spans. *Journal of the Architectural Institute of Korea Planning & Design*, 32(8), 13–20.
83. Park, S.-J., Kim, J.-H., Maing, M.-J., Ahn, J.-H., Kim, Y.-G., Ham, N.-H. Et al. (2024). Transformation of Buildings and Urban Spaces to Adapt for Future Mobility: A Systematic Literature Review. *Land*, 13(1), 16. <https://doi.org/10.3390/land13010016>
84. Brossa, M. (2023). From zeilenbau slabs to community-building clusters. The contribution of Seoul to the planning of mass housing estates, 1962–2008. *Planning Perspectives*, 38(5), 1041–1077. <https://doi.org/10.1080/02665433.2022.2150280>
85. Raviz, S. R. H., Eteghad, A. N., Guardiola, E. U., & Aira, A. A. (2015). Flexible housing: The role of spatial organization in achieving functional efficiency. *ArchNet-IJAR: International Journal of Architectural Research*, 9(2), 65.
86. Heba, K., Selim, H. S., & Ghazala, A. A. A. (2023). High Rise Buildings: Assessment Approach. *Architecture Research*, 13, 23–32. <https://doi.org/10.5923/j.arch.20231301.03>
87. Aslantamer, Ö. N., & Ilgin, H. E. (2024). Space Efficiency of Tall Buildings in Singapore. *Applied Sciences*, 14(18), 8397. <https://doi.org/10.3390/app14188397>
88. Ilgin, H. E. (2023). Interrelations of slenderness ratio and main design criteria in supertall buildings. *International Journal of Building Pathology and Adaptation*, 41(6), 139–161. <https://doi.org/10.1108/IJBPA-07-2022-0102>
89. Ilgin, H. E. (2022). Core Design and Space Efficiency in Contemporary Supertall Office Buildings. In K. Al-Kodmany, P. Du, & M. M. Ali (Eds.), *Sustainable High-Rise Buildings: Design, Technology, and Innovation*. The Institution of Engineering and Technology (IET). https://doi.org/10.1049/PBBE003E_ch8
90. Kim, D. K. (2006). The natural environment control system of Korean traditional architecture: Comparison with Korean contemporary architecture. *Building and Environment*, 41(12), 1905–1912. <https://doi.org/10.1016/j.buildenv.2005.07.007>
91. Li, P., Xiao, H., Li, X., Hu, W., Gu, S., & Yu, Z. (2018). Ecological risk Evaluation and Green Infrastructure planning for coping with global climate change, a case study of Shanghai, China. *IOP Conference Series: Earth and Environmental Science*, 108(4), 042077. <https://doi.org/10.1088/1755-1315/108/4/042077>
92. Günel, M. H., & Ilgin, H. E. (2014). *Yüksek Bina: Taşıyıcı Sistem ve Aerodinamik Form* (in Turkish). METU Faculty of Architecture Press.
93. Zhao, X., Mao, X., & Lu, Y. (2024). Skyscraper height and urban development in developing countries: economy and trade. *Kybernetes*, 53(4), 1505–1527. <https://doi.org/10.1108/K-10-2022-1484>
94. Karamoozian, M., & Zhang, H. (2025). Obstacles to green building accreditation during operating phases: Identifying challenges and solutions for sustainable development. *Journal of Asian Architecture and Building Engineering*, 24(1), 350–366. <https://doi.org/10.1080/13467581.2023.2280697>

Appendix A

Table A1. City, building height, number of stories, completion year, and form.

#	Building Name	City	Height (Meters)	# of Stories	Completion Date	Building form
1	Haeundae I Park Marina Tower 2	Busan	292	72	2011	Prismatic
2	Busan International Finance Center Landmark Tower	Busan	289	63	2014	Prismatic
3	Doosan Haeundae We've the Zenith Tower B	Busan	282	75	2011	Prismatic
4	Haeundae I Park Marina Tower 1	Busan	273	66	2011	Prismatic
5	Doosan Haeundae We've the Zenith Tower C	Busan	265	70	2011	Prismatic
6	Tower Palace Three, Tower G	Seoul	264	73	2004	Prismatic
7	Mokdong Hyperion Tower A	Seoul	256	69	2003	Prismatic
8	Hwaseong Dongtan Metapolis 101	Hwaseong	249	66	2010	Prismatic
9	Hwaseong Dongtan Metapolis 104	Hwaseong	247	66	2010	Prismatic
10	Parc1 Tower II	Seoul	247	51	2020	Setback
11	FKI Tower	Seoul	245	50	2013	Prismatic
12	Bucheon Kumho Richensia Tower 1	Bucheon	241	66	2012	Prismatic
13	Bucheon Kumho Richensia Tower 2	Bucheon	241	66	2012	Prismatic
14	Mokdong Hyperion Tower B	Seoul	239	63	2003	Prismatic
15	The First World Tower 1	Incheon	237	67	2009	Prismatic
16	The First World Tower 2	Incheon	237	67	2009	Prismatic
17	The First World Tower 3	Incheon	237	67	2009	Prismatic
18	The First World Tower 4	Incheon	237	67	2009	Prismatic
19	Tower Palace One, Tower B	Seoul	234	66	2002	Prismatic
20	Tanhyun Doosan We've the Zenith 105	Goyang	230	59	2013	Prismatic
21	Ilsan Yojin Y-City Tower 103	Goyang	230	59	2016	Prismatic
22	Ilsan Yojin Y-City Tower 105	Goyang	230	59	2016	Prismatic
23	Ilsan Yojin Y-City Tower 102	Goyang	225	58	2016	Prismatic
24	Ilsan Yojin Y-City Tower 104	Goyang	225	58	2016	Prismatic
25	Tanhyun Doosan We've the Zenith 104	Goyang	224	57	2013	Prismatic
26	Hwaseong Dongtan Metapolis 102	Hwaseong	224	60	2010	Prismatic
27	Ilsan Yojin Y-City Tower 106	Goyang	221	57	2016	Prismatic
28	Seoul Hall TP Tower	Seoul	220	42	2024	Prismatic
29	Tanhyun Doosan We've the Zenith 102	Goyang	215	54	2013	Prismatic
30	Tanhyun Doosan We've the Zenith 103	Goyang	215	54	2013	Prismatic
31	Tanhyun Doosan We've the Zenith 106	Goyang	215	54	2013	Prismatic
32	BI CITY Office	Busan	215	49	2018	Prismatic
33	Ilsan Yojin Y-City Tower 101	Goyang	214	55	2016	Prismatic
34	Centum Star B	Busan	212	60	2008	Prismatic
35	Tanhyun Doosan We've the Zenith 101	Goyang	212	53	2013	Prismatic
36	Tanhyun Doosan We've the Zenith 107	Goyang	212	53	2013	Prismatic
37	Tower Palace One, Tower A	Seoul	209	59	2002	Prismatic
38	Tower Palace One, Tower C	Seoul	209	59	2002	Prismatic
39	Tanhyun Doosan We've the Zenith 108	Goyang	206	51	2013	Prismatic
40	Acro Seoul Forest Tower B	Seoul	206	49	2020	Prismatic
41	Acro Seoul Forest Tower A	Seoul	206	49	2021	Prismatic
42	Haeundae I Park Marina Tower 3	Busan	205	46	2011	Prismatic
43	Golden View Central Park Tower A	Busan	205	58	2018	Prismatic
44	Golden View Central Park Tower B	Busan	205	58	2018	Prismatic
45	Golden View Central Park Tower C	Busan	205	58	2018	Prismatic
46	Star Tower, Gangnam Finance Center	Seoul	204	45	2001	Prismatic
47	Hwaseong Dongtan Metapolis 103	Hwaseong	203	55	2010	Prismatic

Table A1. (Continued)

48	Samsung Electronics Corporation HQ	Seoul	203	44	2008	Free
49	Mokdong Hyperion Tower C	Seoul	201	54	2003	Prismatic
50	Marina G7 Building A	Busan	200	61	2021	Prismatic
51	Marina G7 Building B	Busan	200	61	2021	Prismatic
52	Conrad Seoul	Seoul	199	38	2012	Prismatic
53	Gundae Posco The Star City Tower A	Seoul	196	58	2008	Prismatic
54	Raemian Caelitus Tower A	Seoul	196	56	2015	Prismatic
55	Tower Palace Two, Tower E	Seoul	191	55	2003	Prismatic
56	Tower Palace Two, Tower F	Seoul	191	55	2003	Prismatic
57	Cheongna Exllu Tower A	Incheon	190	55	2011	Prismatic
58	Cheongna Exllu Tower B	Incheon	190	55	2011	Prismatic
59	Daesung D-Cube City Headquarters	Seoul	190	44	2011	Prismatic
60	Songdo Posco Centroad Tower 1	Incheon	190	45	2011	Free
61	Centum Star C	Busan	189	52	2008	Prismatic

Appendix B

Table B1. Function, core type, structural system, and structural material.

#	Building Name	Function	Core Type	Structural System	Structural Material
1	Haeundae I Park Marina Tower 2	Residential	Central	Outriggered frame	Composite
2	Busan International Finance Center Landmark Tower	Office	Central	Outriggered frame	Concrete
3	Doosan Haeundae We've the Zenith Tower B	Residential	Central	Outriggered frame	Concrete
4	Haeundae I Park Marina Tower 1	Residential	Central	Outriggered frame	Composite
5	Doosan Haeundae We've the Zenith Tower C	Residential	Central	Outriggered frame	Concrete
6	Tower Palace Three, Tower G	Residential	Central	Buttressed core	Composite
7	Mokdong Hyperion Tower A	Residential	Central	Outriggered frame	Concrete
8	Hwaseong Dongtan Metapolis 101	Residential	Central	Outriggered frame	Concrete
9	Hwaseong Dongtan Metapolis 104	Residential	Central	Outriggered frame	Concrete
10	Parc1 Tower II	Office	Central	Outriggered frame	Composite
11	FKI Tower	Office	Central	Outriggered frame	Composite
12	Bucheon Kumho Richensia Tower 1	Residential	Central	Outriggered frame	Concrete
13	Bucheon Kumho Richensia Tower 2	Residential	Central	Outriggered frame	Concrete
14	Mokdong Hyperion Tower B	Residential	Central	Outriggered frame	Concrete
15	The First World Tower 1	Residential	Central	Outriggered frame	Concrete
16	The First World Tower 2	Residential	Central	Outriggered frame	Concrete
17	The First World Tower 3	Residential	Central	Outriggered frame	Concrete
18	The First World Tower 4	Residential	Central	Outriggered frame	Concrete
19	Tower Palace One, Tower B	Residential	Central	Outriggered frame	Composite
20	Tanhyun Doosan We've the Zenith 105	Residential	Central	Outriggered frame	Concrete
21	Ilsan Yojin Y-City Tower 103	Residential	Central	Outriggered frame	Concrete
22	Ilsan Yojin Y-City Tower 105	Residential	Central	Outriggered frame	Concrete
23	Ilsan Yojin Y-City Tower 102	Residential	Central	Outriggered frame	Concrete
24	Ilsan Yojin Y-City Tower 104	Residential	Central	Outriggered frame	Concrete
25	Tanhyun Doosan We've the Zenith 104	Residential	Central	Outriggered frame	Concrete
26	Hwaseong Dongtan Metapolis 102	Residential	Central	Outriggered frame	Concrete
27	Ilsan Yojin Y-City Tower 106	Residential	Central	Outriggered frame	Concrete
28	Seoul Hall TP Tower	Office	Central	Outriggered frame	Composite
29	Tanhyun Doosan We've the Zenith 102	Residential	Central	Outriggered frame	Concrete
30	Tanhyun Doosan We've the Zenith 103	Residential	Central	Outriggered frame	Concrete
31	Tanhyun Doosan We've the Zenith 106	Residential	Central	Outriggered frame	Concrete
32	BI CITY Office	Office	Central	Outriggered frame	Concrete
33	Ilsan Yojin Y-City Tower 101	Residential	Central	Outriggered frame	Concrete
34	Centum Star B	Residential	Central	Outriggered frame	Concrete
35	Tanhyun Doosan We've the Zenith 101	Residential	Central	Outriggered frame	Concrete
36	Tanhyun Doosan We've the Zenith 107	Residential	Central	Outriggered frame	Concrete
37	Tower Palace One, Tower A	Residential	Central	Outriggered frame	Composite
38	Tower Palace One, Tower C	Residential	Central	Outriggered frame	Composite
39	Tanhyun Doosan We've the Zenith 108	Residential	Central	Outriggered frame	Concrete
40	Acro Seoul Forest Tower B	Residential	Central	Outriggered frame	Concrete
41	Acro Seoul Forest Tower A	Residential	Central	Outriggered frame	Concrete
42	Haeundae I Park Marina Tower 3	Residential	Central	Outriggered frame	Composite
43	Golden View Central Park Tower A	Residential	Central	Outriggered frame	Concrete
44	Golden View Central Park Tower B	Residential	Central	Outriggered frame	Concrete
45	Golden View Central Park Tower C	Residential	Central	Outriggered frame	Concrete
46	Star Tower, Gangnam Finance Center	Office	Central	Outriggered frame	Concrete
47	Hwaseong Dongtan Metapolis 103	Residential	Central	Outriggered frame	Concrete

Table B1. (Continued)

48	Samsung Electronics Corporation HQ	Office	Central	Shear walled frame	Composite
49	Mokdong Hyperion Tower C	Residential	Central	Outriggered frame	Concrete
50	Marina G7 Building A	Residential	Central	Shear walled frame	Concrete
51	Marina G7 Building B	Residential	Central	Shear walled frame	Concrete
52	Conrad Seoul	Hotel	Central	Outriggered frame	Composite
53	Gundae Posco The Star City Tower A	Residential	Central	Shear walled frame	Concrete
54	Raemian Caelitus Tower A	Residential	Central	Shear walled frame	Concrete
55	Tower Palace Two, Tower E	Residential	Central	Outriggered frame	Composite
56	Tower Palace Two, Tower F	Residential	Central	Outriggered frame	Composite
57	Cheongna Exllu Tower A	Residential	Central	Shear walled frame	Concrete
58	Cheongna Exllu Tower B	Residential	Central	Shear walled frame	Concrete
59	Daesung D-Cube City Headquarters	Mixed-use (Hotel + Office)	Central	Shear walled frame	Composite
60	Songdo Posco Centroad Tower 1	Hotel	Central	Outriggered frame	Concrete
61	Centum Star C	Residential	Central	Outriggered frame	Concrete

Appendix C

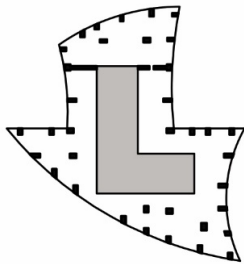
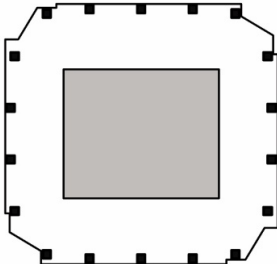
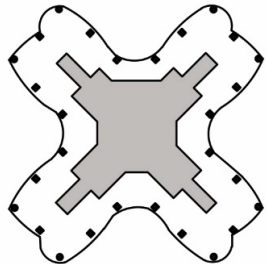
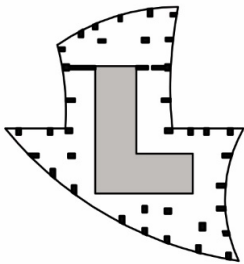
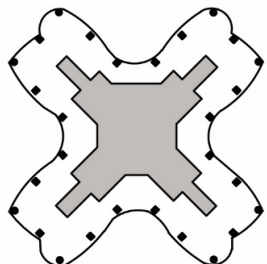
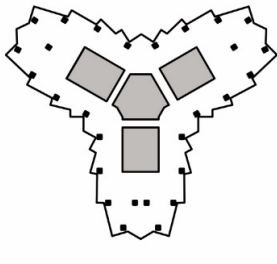
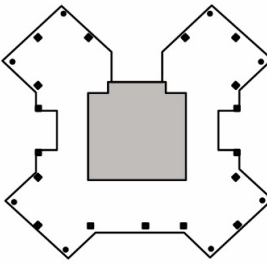
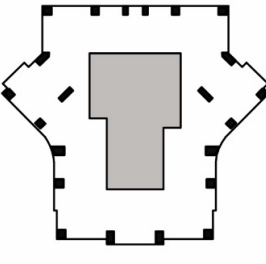
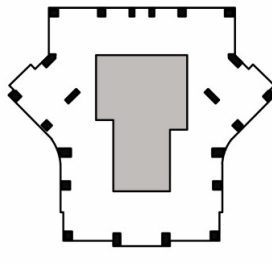
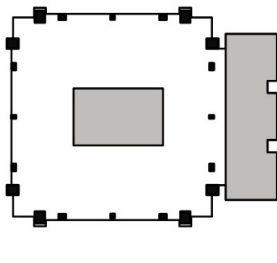
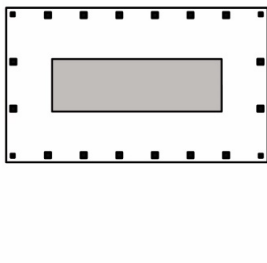
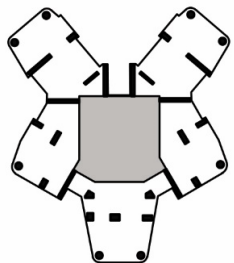
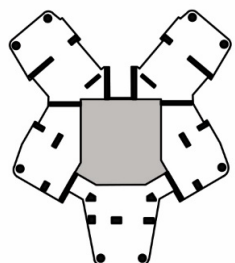
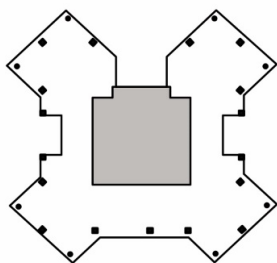
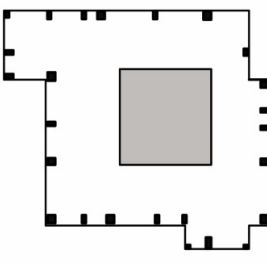
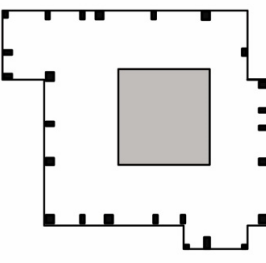
#- Building Name (Buildings are listed from highest to lowest.)								# - 1 to 16
Space Efficiency *				Core/GFA **				
1-Haeundae I Park Marina Tower 2		2-Busan International Finance Center Landmark Tower		3-Doosan Haeundae We've the Zenith Tower B		4-Haeundae I Park Marina Tower 1		
72%	24%	68%	30%	68%	30%	72%	24%	
								
5-Doosan Haeundae We've the Zenith Tower C		6-Tower Palace Three, Tower G		7-Mokdong Hyperion Tower A		8-Hwaseong Dongtan Metapolis 101		
68%	30%	78%	21%	78%	21%	74%	23%	
								
9-Hwaseong Dongtan Metapolis 104		10-Parc1 Tower II		11-FKI Tower		12-Bucheon Kumho Richensia Tower 1		
74%	23%	72%	26%	77%	22%	74%	21%	
								
13-Bucheon Kumho Richensia Tower 2		14-Mokdong Hyperion Tower B		15-The First World Tower 1		16-The First World Tower 2		
74%	21%	78%	21%	81%	17%	81%	17%	
								

Figure C1. Space efficiency and core-to-GFA ratio.

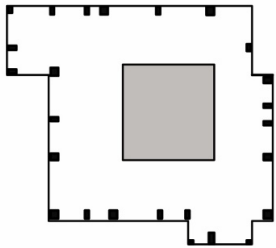
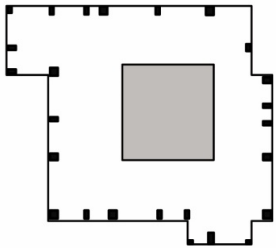
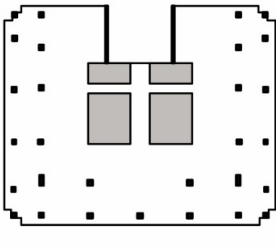
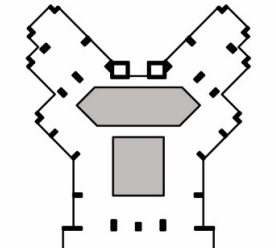
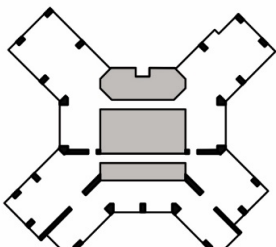
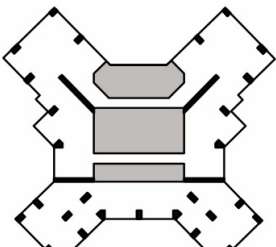
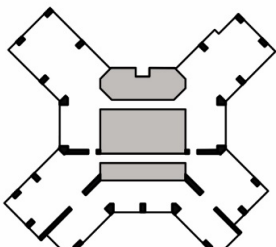
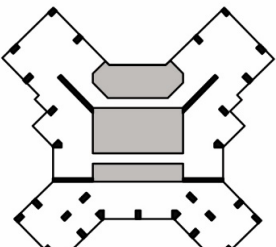
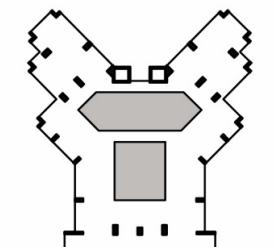
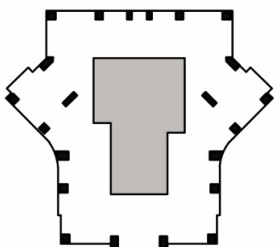
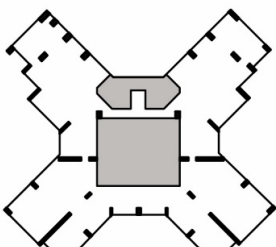
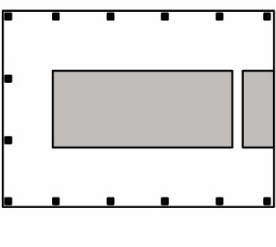
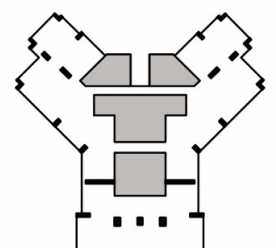
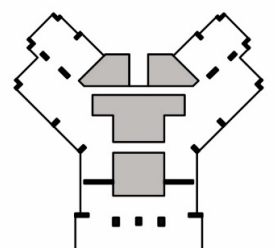
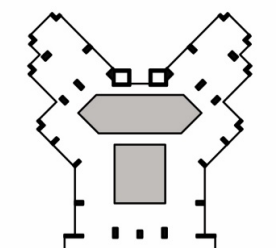
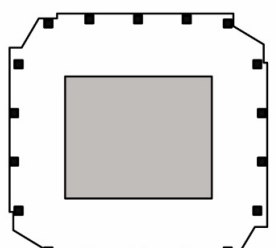
#- Building Name (Buildings are listed from highest to lowest.)							
Space Efficiency *				Core/GFA **			
17-The First World Tower 3		18-The First World Tower 4		19-Tower Palace One, Tower B		20-Tanhyun Doosan We've the Zenith 105	
81%	17%	81%	17%	87%	11%	78%	19%
							
21-Ilsan Yojin Y-City Tower 103		22-Ilsan Yojin Y-City Tower 105		23-Ilsan Yojin Y-City Tower 102		24-Ilsan Yojin Y-City Tower 104	
77%	20%	75%	21%	77%	20%	75%	21%
							
25-Tanhyun Doosan We've the Zenith 104		26-Hwaseong Dongtan Metapolis 102		27-Ilsan Yojin Y-City Tower 106		28-Seoul Hall TP Tower	
78%	19%	74%	23%	78%	19%	69%	30%
							
29-Tanhyun Doosan We've the Zenith 102		30-Tanhyun Doosan We've the Zenith 103		31-Tanhyun Doosan We've the Zenith 106		32-BI CITY Office	
75%	22%	75%	22%	78%	19%	69%	30%
							

Figure C1. (Continued)

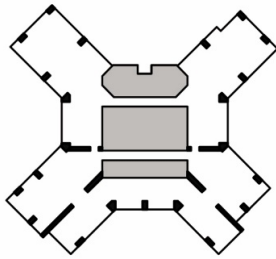
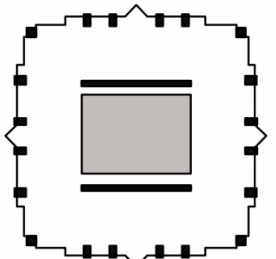
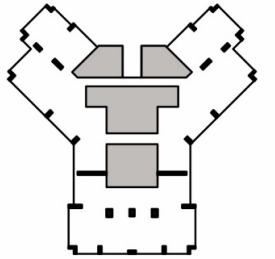
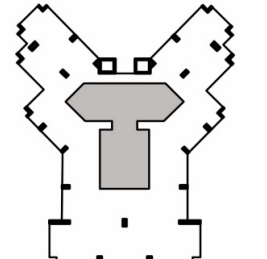
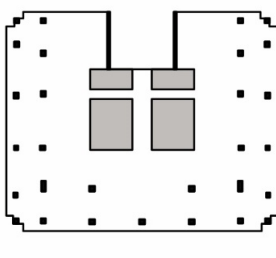
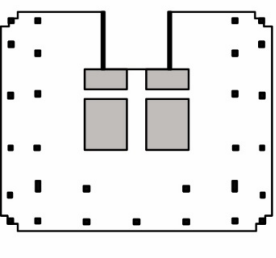
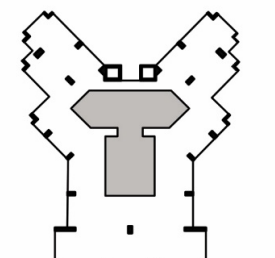
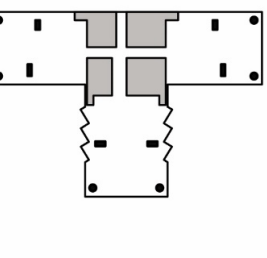
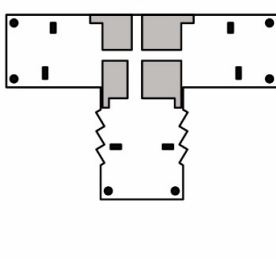
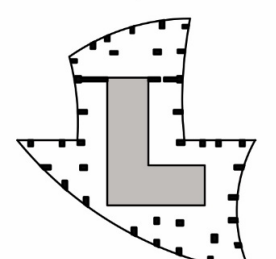
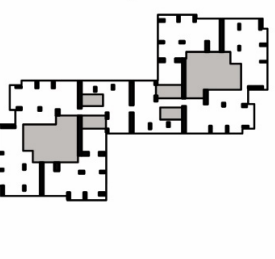
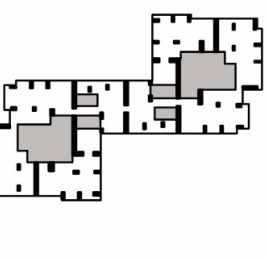
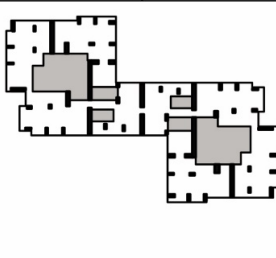
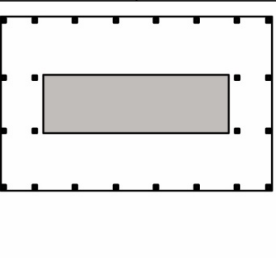
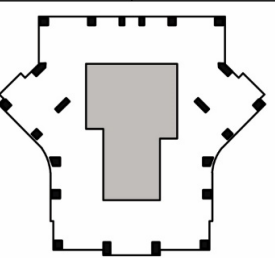
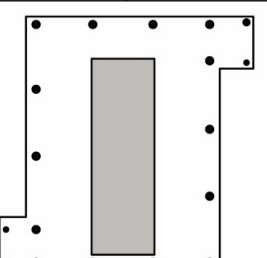
#- Building Name (Buildings are listed from highest to lowest.)								# - 33 to 48
Space Efficiency *				Core/GFA **				
33-Ilsan Yojin Y-City Tower 101		34-Centum Star B		35-Tanhyun Doosan We've the Zenith 101		36-Tanhyun Doosan We've the Zenith 107		
77%	20%	79%	18%	75%	22%	79%	19%	
								
37-Tower Palace One, Tower A		38-Tower Palace One, Tower C		39-Tanhyun Doosan We've the Zenith 108		40-Acro Seoul Forest Tower B		
87%	11%	87%	11%	79%	19%	81%	18%	
								
41-Acro Seoul Forest Tower A		42-Haeundae I Park Marina Tower 3		43-Golden View Central Park Tower A		44-Golden View Central Park Tower B		
81%	18%	72%	24%	74%	21%	74%	21%	
								
45-Golden View Central Park Tower C		46-Star Tower, Gangnam Finance Center		47-Hwaseong Dongtan Metapolis 103		48-Samsung Electronics Corporation HQ		
74%	21%	76%	23%	74%	23%	76%	23%	
								

Figure C1. (Continued)