International Journal of Urban Management and Energy Sustainability (IJUMES)

Homepage: http://www.ijumes.com

CASE STUDY RESEARCH PAPER

Evaluating the Performance of Slab Building Morphotypes in the Contemporary Urban Fabric: A Parametric-Morphometric Approach

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ARTICLE INFO

Article History:
Received 2025-02-05
Revised 2026-07-01
Accepted 2026-07-09

Keywords:
Parametric analysis; slab morphotype; solar access; Space matrix; street-canyon aspect ratio; urban morphology

DOI: 10.22034/ijumes.2026.2089601.1366

ABSTRACT

The slab a free-standing linear building bar repeated in parallel rows is among the most pervasive building morphotypes of the contemporary city, yet its environmental performance varies enormously with the geometric parameters that govern its configuration. The central problem addressed in this study is that slab morphotypes are routinely deployed in contemporary urban fabrics on the basis of land-economic and constructional convenience rather than any systematic evaluation of their urban-sustainability performance, with the result that environmentally inferior configurations are reproduced at scale. The objective of this research is therefore to evaluate, comparatively and quantitatively, how the performance of slab morphotypes on a set of urban-sustainability indicators varies with their defining geometric parameters, and to identify the configurations that optimize that performance. Adopting an analytical–applied design within a post-positivist paradigm, a parametric family of one hundred and forty-four slab configurations was generated by systematically varying building height, bar spacing, bar depth, and orientation, and each configuration was evaluated on six sustainability indicators solar access, daylight, ventilation, open-space provision, permeability, and density efficiency computed through established morphometric relationships and combined into a weighted sustainability score. Findings indicate that bar spacing is by far the strongest determinant of sustainability performance ($r = +0.93$), that building height is moderately detrimental ($r = -0.28$), and that wide-spaced low- to mid-rise east–west-oriented slabs substantially outperform compact high-rise configurations, the highest-scoring morphotype reaching 0.72 against 0.22 for the worst. The study concludes that the sustainability performance of slab morphotypes is governed primarily by the spacing and height that determine solar access and open space, and that contemporary design guidance should constrain these parameters rather than density alone.

Running Title: : Slab Building Morphotypes in the Contemporary Urban Fabric

NUMBER OF REFERENCES
30

NUMBER OF FIGURES
06

NUMBER OF TABLES
04

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INTRODUCTION

The physical form of the contemporary city is, to a remarkable degree, an aggregation of a small number of recurring buildings morphotypes. Among these, the slab a linear, free-standing building bar, typically repeated in parallel rows across a site has become a defining element of post-war and contemporary urban development worldwide, from the modernist housing estates of mid-century Europe to the high-rise residential compounds of rapidly urbanizing Asia and the Middle East. Its popularity rests on constructional efficiency, ease of repetition, and the straightforward way it converts a development parcel into saleable floor area. (Ko, 2013, Leng et al., 2020, Li et al., 2018) Yet the environmental consequences of the slab morphotype are far from uniform. The same nominal building type can, depending on its height, the spacing between bars, the depth of each bar, and its orientation to the sun and prevailing wind, produce radically different outcomes for solar access, daylight, natural ventilation, open-space provision, and microclimate. A growing body of morphological and building-physics research demonstrates that these geometric parameters, rather than the building type label, are what determine performance (Strømann-Andersen & Sattrup, 2011; Chatzipoulka et al., 2016; Liu et al., 2024). The dominant analytical traditions address this problem only partially. Building-energy simulation evaluates individual configurations in depth but rarely surveys the full parameter space; urban-morphometric approaches such as the Space-matrix method of Berghauser Pont and Haupt (2010) characterize density and form systematically but do not, by themselves, translate form into environmental performance. (Natanian et al., 2019, Quan and Li, 2021, Rode et al., 2014, Ratti et al., 2005) What is missing is a systematic, comparative evaluation that traverses the parameter space of the slab morphotype and links each configuration to a coherent set of sustainability indicators. The contemporary urban fabric, in which slabs are reproduced at scale with little morphological scrutiny, makes this gap consequential: an environmentally inferior configuration, once normalized, is replicated across entire districts. (Salvati et al., 2017, Sanaieian et al., 2014, Steadman et al., 2009, Taleghani et al., 2014, Yang et al., 2017) What The present study addresses this gap directly. It develops a parametric family of slab morphotypes, computes for each a set of established morphometric and environmental indicators, combines them into a weighted urban-sustainability score, and analyses how that score varies across the parameter space. The aim is neither to evaluate a single project nor to model a specific city, but to derive generalizable, transferable design knowledge about which slab configurations perform well on sustainability grounds and why.

MATERIALS AND METHODS

Building morphotypes and urban form

Urban morphology distinguishes a limited repertoire of generic building morphotypes among them the perimeter block, the point tower or pavilion, and the slab each with characteristic relationships between built form and open space. Comparative studies of these types consistently find that they occupy distinct regions of the density–performance space and that their environmental behavior cannot be inferred from density alone. Strømann-Andersen and Sattrup (2011) and Zhang et al. (2019), in a parametric energy analysis of the pavilion, slab, and perimeter block, showed that urban form can alter total building energy use by a factor that rivals the building envelope itself, and that the slab's performance is especially sensitive to spacing and orientation. The systematic measurement of urban form is most fully developed in the Space-matrix framework of Berghauser Pont and Haupt (2010) and Zhu et al. (2020), which characterizes any fabric through four interdependent indicators: the Floor Space Index (FSI, built floor area per unit site), the Ground Space Index (GSI, building coverage), the Open Space Ratio (OSR, non-built ground per unit floor area), and the average number of layers (L).

These indicators together give a fabric its 'spatial fingerprint' and allow morphotypes of identical density but different form to be distinguished precisely the discrimination required to evaluate slab configurations. The present study adopts FSI, GSI, and OSR as the morphometric backbone of its analysis and situates each morphotype within the Space-matrix plane.

Form, solar access, and the street canyon

The environmental dimension of slab morphology is governed above all by the geometry of the space between bars, conventionally described by the street-canyon aspect ratio (building height divided by spacing, H/W) and the associated sky-view factor (SVF). A substantial literature establishes that higher aspect ratios and lower sky-view factors reduce solar access, daylight, and the dispersal of heat and pollutants (Mohajeri et al., 2019; Krüger et al., 2011; Chatzipoulka et al., 2016, Chokhachian et al., 2020, Javanroodi et al., 2018). The systematic review of Liu et al. (2024) synthesises this evidence, reporting that building density, plot ratio, and canyon aspect ratio correlate negatively with solar-radiation acquisition, while building interval and sky-view factor correlate positively. Orientation compounds these effects: Mohajeri et al. (2019) demonstrate that canyon and facade orientation strongly condition the annual solar radiation received, with south-facing facades in the northern hemisphere favored by east–west-oriented slab bars receiving substantially more than other orientations. Taken together, this literature implies a clear set of expectations against which a parametric evaluation can be tested: that wider spacing, lower height, and east–west orientation should improve the environmental performance of slab morphotypes, while compact, tall, unfavorably oriented configurations should degrade it. It also implies an inherent tension with the density-maximizing logic that drives slab deployment in the contemporary city, since the parameters that improve environmental performance generally reduce floor-area yield. (Boyko et al., 2011; Martins et al., 2014; Chatzipoulka et al., 2016, Chokhachian et al., 2020, Javanroodi et al., 2018). The analysis below quantifies this tension across the full parameter space. This study adopts an analytical–applied research design within a post-positivist paradigm. It is analytical in deriving sustainability performance from the measurable geometry of building form, and applied in producing transferable design guidance. No single case study is used: the unit of analysis is the abstract slab morphotype, evaluated parametrically so that the conclusions are generalizable rather than site-specific.

Parametric definition of the slab morphotype

The slab morphotype was defined on a standard square fabric tile of one hundred metres on each side, occupied by parallel linear building bars spanning the tile. Four geometric parameters were varied systematically: building height (5, 8, 12, and 16 storeys at 3.2 m per storey), bar spacing (15, 20, 25, and 30 m), bar depth (12, 15, and 18 m), and orientation (0°, i.e. bars running east–west with long facades to the south and north; 45°; and 90°, bars running north–south). The full factorial combination yielded one hundred and forty-four distinct morphotype configurations. The schematic logic of the morphotype and its parameters is shown in Figure 1, and the street-canyon section that governs solar access in Figure 2. (Fig. 1 and 2)

Sustainability indicators

For each configuration, a set of morphometric and environmental indicators was computed from the geometry. The morphometric indicators follow the Space-matrix definitions: the Ground Space Index (GSI) as built footprint over tile area, the Floor Space Index (FSI) as gross floor area over tile area, and the Open Space Ratio (OSR) as non-built ground over floor area. The environmental indicators were derived from established morphological relationships: the street-canyon aspect ratio (H/W) and the corresponding sky-view factor (SVF); a solar-access measure combining SVF with an orientation factor reflecting the documented advantage of south-facing facades; a daylight measure combining SVF with spacing; a ventilation measure reflecting spacing and bar orientation relative to prevailing wind; an open-space provision measure derived from OSR; a ground-permeability measure; and a density-efficiency measure derived from FSI. The definitions are summarized in Table 1. (Tab. 1)

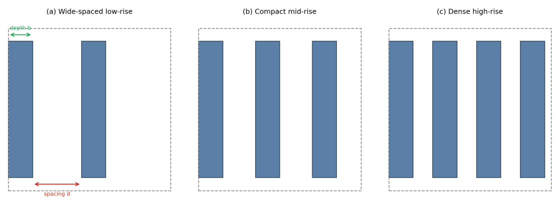

Figure 1: Schematic plan of the slab morphotype on a 100 m fabric tile under three representative configurations, showing the bar-depth (b) and bar-spacing (d) parameters (Source: Authors)

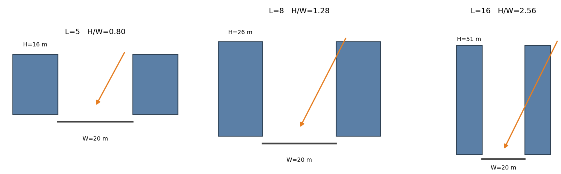

Figure 2: Street-canyon section between slab bars for three building heights, illustrating the aspect ratio (H/W) that governs solar access and sky-view factor (Source: Authors)

Table 1: Morphometric and environmental indicators used to evaluate slab morphotypes, with their derivation and direction of influence on sustainability (Source: Authors)

Indicator	Definition / derivation	Direction
Floor Space Index (FSI)	Gross floor area ÷ tile area (Spacematrix)	Context
Ground Space Index (GSI)	Building footprint ÷ tile area (coverage)	Context
Open Space Ratio (OSR)	(1 − GSI) ÷ FSI (spaciousness)	Higher = better
Canyon aspect ratio (H/W)	Building height ÷ bar spacing	Lower = better
Sky-view factor (SVF)	cos(arctan(H ÷ (W/2))) for the inter-bar canyon	Higher = better
Solar access	SVF × orientation factor (E–W favoured)	Higher = better
Daylight	Weighted SVF and spacing	Higher = better
Ventilation	Spacing and bar orientation to prevailing wind	Higher = better
Open-space provision	Normalised OSR	Higher = better
Permeability	Number and width of inter-bar gaps	Higher = better
Density efficiency	Normalised FSI (floor-area yield)	Higher = better

Composite sustainability score and analysis

The six environmental and provision indicators (solar access, daylight, ventilation, open-space provision, permeability, and density efficiency) were each normalized to a 0–1 scale across the configuration set and combined into a weighted composite sustainability score. The weights solar access 0.22, density efficiency 0.20, daylight 0.16, open-space provision 0.16, ventilation 0.14, and permeability 0.12 reflect the emphasis placed on solar and daylight performance in the reviewed morphological literature while retaining density efficiency as a substantial competing objective. The relationship between each design parameter and the composite score was then examined through correlation and sensitivity analysis, and four representative archetypes were profiled in detail. All computation was performed in Python (NumPy).

FINDINGS AND DISCUSSION

Across the one hundred and forty-four configurations, the composite sustainability score ranged from 0.22 to 0.72, a more than threefold spread that confirms the decisive influence of geometric configuration on the environmental performance of a single nominal building type. When the configurations are situated in the Space-matrix (FSI–GSI) plane and colored by sustainability score, a clear gradient emerges: lower-FSI, higher-OSR configurations occupy the high-performance region, while the dense, high-FSI, low-OSR configurations cluster in the low-performance region. (Fig. 3)

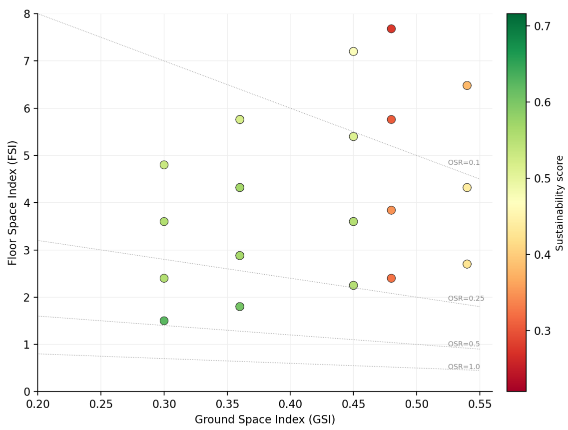

Figure 3:The 144 slab configurations situated in the Space-matrix (FSI–GSI) plane and colored by composite sustainability score; dotted lines are OSR iso-contours (Source: Authors)

The sensitivity analysis quantifies which parameters drive this gradient. Bar spacing is overwhelmingly the strongest determinant, correlating with the sustainability score at r = +0.93: widening the gap between bars improves solar access, daylight, ventilation, and open space simultaneously. Building height correlates negatively (r = −0.28), reflecting the rising canyon aspect ratio and falling sky-view factor of taller configurations, while bar depth has a weak negative effect (r = −0.16) and orientation, considered across the full set, a negligible linear effect (r = −0.01) that nonetheless matters within fixed-geometry comparisons. The parameter sensitivities are shown in Figure 4 and summarized in Table 2. (Tab. 2)

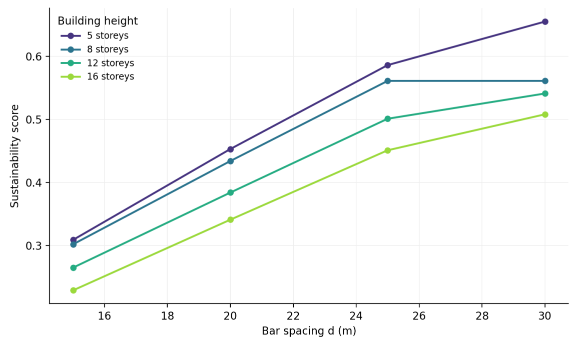

Figure 4: Composite sustainability score as a function of bar spacing for four building heights (east–west orientation, 15 m bar depth); wider spacing and lower height raise the score (Source: Authors)

Table 2: Sensitivity of the composite sustainability score to each slab design parameter (Pearson correlation across the 144 configurations) (Source: Authors)

Design parameter	Correlation with score	Interpretation
Bar spacing (d)	+0.93	Dominant positive driver
Building height (L)	−0.28	Moderate negative driver
Bar depth (b)	−0.16	Weak negative driver
Orientation	−0.01	Negligible across set; matters locally

To make the trade-offs concrete, four representative archetypes were profiled across the six indicators. ST-1, a wide-spaced low-rise east–west slab, achieves the highest sustainability score by excelling on solar access, daylight, and open space at the cost of density. ST-2, a compact mid-rise east–west slab, balances moderate density against moderate environmental performance. ST-3, a compact high-rise north–south slab, maximizes density but records the weakest environmental performance of the four. ST-4, a wide-spaced high-rise east–west slab, recovers some environmental performance relative to ST-3 by retaining spacing and favorable orientation despite its height. The indicator profiles are shown in Figure 6 and the values in Table 3. (Tab. 3 and 4)

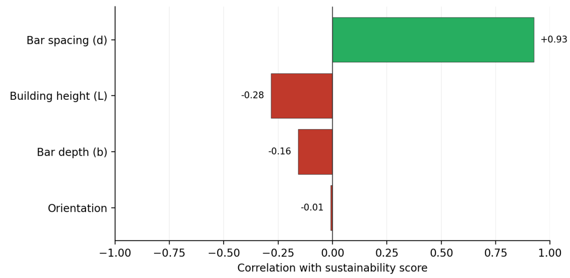

Figure 5: Parameter sensitivity of the composite sustainability score; green bars denote positive and red bars negative correlation (Source: Authors)

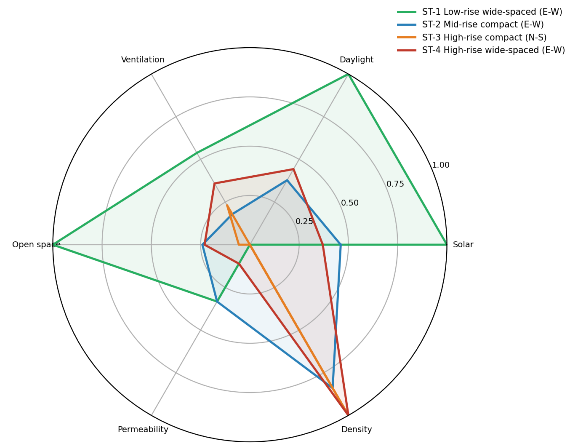

Figure 6: Normalized indicator profiles of the four representative slab archetypes across the six sustainability dimensions (Source: Authors)

Table 3: Morphometric and sustainability values for the four representative slab archetypes (Source: Authors)

Indicator	ST-1	ST-2	ST-3	ST-4
FSI	1.50	3.60	7.20	4.32
GSI	0.30	0.45	0.45	0.36
OSR	0.47	0.15	0.08	0.15
Canyon H/W	0.53	1.28	3.41	1.54
Sky-view factor	0.68	0.36	0.14	0.31
Sustainability score	0.655	0.434	0.241	0.453

Table 4: Best- and worst-performing slab configurations across the parametric set (source: authors).

Configuration	Parameters	Score
Best-performing	b=12 m, d=30 m, L=5, E–W	0.716
Worst-performing	b=18 m, d=15 m, L=16, E–W	0.220
Range across 144 configs	–	0.22 – 0.72

FINDINGS AND DISCUSSION

The dominance of bar spacing in the sensitivity analysis is the central substantive finding, and it is fully consistent with the morphological literature. Spacing simultaneously governs the street-canyon aspect ratio and the sky-view factor between bars, and through them the solar access, daylight, ventilation, and open-space provision that constitute the bulk of the sustainability score. The strong positive correlation ($r = +0.93$) confirms, across a full parameter space, the relationships that prior single-configuration studies established in particular settings. The moderate negative effect of height, and the contrasting profiles of the archetypes, expose the fundamental tension at the heart of contemporary slab deployment. The configurations that maximize floor-area yield tall, compact slabs such as ST-3 are precisely those that perform worst environmentally, because height raises the canyon aspect ratio and compactness eliminates the open space and solar access that sustainability depends on. Conversely, the highest-scoring configurations sacrifice density for environmental quality. This trade-off is not absolute, however: the comparison of ST-3 and ST-4 demonstrates that, at a given height, retaining generous spacing and favorable east–west orientation can recover a substantial part of the environmental performance lost to verticality, pointing toward compromise configurations that reconcile moderate density with acceptable sustainability. The practical implication is that design guidance for contemporary urban fabrics should regulate the spacing and height of slab morphotypes directly, rather than relying on density (FSI) limits alone, since identical densities can correspond to widely divergent sustainability outcomes depending on configuration. The Space-matrix positioning of the configurations (Fig. 3) provides exactly the instrument planners need: it allows a target density to be held constant while selecting the configuration within that density that maximizes sustainability.

This study evaluated the urban-sustainability performance of slab building morphotypes through a parametric–morphometric analysis of one hundred and forty-four configurations, varying building height, bar spacing, bar depth, and orientation and assessing each on six sustainability indicators combined into a composite score. Four conclusions follow. First, the sustainability performance of a single nominal building type varies more than threefold (0.22 to 0.72) with geometric configuration alone, demonstrating that the slab label conveys little about environmental performance and that configuration must be evaluated explicitly. Second, bar spacing is the dominant determinant of performance ($r = +0.93$), operating through the street-canyon aspect ratio and sky-view factor that govern solar access, daylight, ventilation, and open space. Third, building height is moderately detrimental and interacts with spacing and orientation, such that wide-spaced, favorably oriented configurations can partially offset the penalty of verticality. Fourth, the highest-performing morphotypes are wide-spaced low- to mid-rise east–west slabs, while compact high-rise slabs perform worst, exposing a structural tension between floor-area yield and environmental quality.

The theoretical contribution of the study is to link the morphometric description of the slab morphotype, through the Space-matrix framework, to a coherent set of environmental performance indicators across a full parameter space, rather than for isolated configurations. The methodological contribution is a transparent, reproducible parametric procedure that can be extended to other morphotypes and indicator sets. The practical contribution is a body of transferable design guidance: that the regulation of slab spacing and height, not density alone, is the effective lever for steering the contemporary urban fabric toward sustainability. The study is subject to limitations. The environmental indicators are computed through established morphological relationships rather than full dynamic simulation, which would refine the absolute values though not, on the evidence of the literature, the comparative rankings; the analysis treats an idealized, repeating fabric tile rather than a real heterogeneous context; and the composite score depends on a defensible but particular weighting. Future research should validate the rankings against dynamic solar and energy simulation, extend the analysis to mixed and hybrid morphotypes, test the weighting through sensitivity and multi-criteria methods, and apply the framework to real urban fabrics to quantify the sustainability gains achievable through morphotype substitution.

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HOW TO CITE THIS ARTICLE

Moeini,M , Rostami,F ,and Saeidipour,S. (2026). Evaluating the Performance of Slab Building Morphotypes in the Contemporary Urban Fabric: A Parametric-Morphometric Approach (e735602). International Journal of Urban Management and Energy Sustainability, 7(1), e735602

DOI:10.22034/ijumes.2025.735602