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PLOT MORPHOLOGY AND RETAIL PATTERNS: A MORPHOLOGICAL ASSESSMENT OF PERIPHERAL RETAIL CLUSTERS

Hulusi Eren EFEOĞLU [1,2]✉, Anssi JOUTSINIEMI [3], Skirmantė MOZŪRIŪNAITĖ [4]

[1]*Aalto University, Espoo, Finland*
[2]*Middle East Technical University, Ankara, Türkiye*
[3]*University of Oulu, Oulu, Finland*
[4]*Vilnius Gediminas Technical University, Vilnius, Lithuania*

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Abstract. Retail clusters represent an important spatial expression of urban vitality, yet how urban form relates to retail patterns remains underexplored, particularly at the plot scale where compositional and configurational attributes intersect. This research examines how plot-level structural and network-based contextual attributes are associated with retail density, agglomeration, and diversity in peripheral areas, and whether they correspond with retail cluster form. The Morphological Assessment Framework (MAF) weights plot attributes by their spatially varying associations with each retail metric, estimated through multiscale geographically weighted regression. Using municipal plot data and retail point-of-interest data, 19 peripheral clusters (5064 plots) were selected from DBSCAN-identified clusters (120, 200, and 216 m) in Ankara, Helsinki, and Vilnius. Retail diversity is positively associated with the configurational character of plots in all cities (0.13–0.60), and retail density with their compositional character, most strongly in Helsinki (0.46). The MAF indicates that these associations are configuration-led in Ankara, composition-led in Helsinki, and intermediate in Vilnius, while cluster form varies between cities rather than with plot morphology. As an analytical framework, the MAF identifies which morphological dimension is most closely associated with retail vitality in each of the three peripheral contexts, rather than assuming uniform effects.

Keywords: urban morphology, retail geography, plot, retail centrality, urban vitality, urban form.

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✉Corresponding author. E-mail: ***eren.efeoglu@aalto.fi***

1. Introduction

Urban vitality is related to the concentration of diverse activities in proximity. As Jacobs (1961) highlights, "wherever we find a city district with an exuberant variety and plenty in its commerce, we are apt to find that it contains a good many other kinds of diversity also, including variety of cultural opportunities, variety of scenes, and a great variety in its population and other users." Areas with varied retail offer thus tend to support broader urban diversity through the interrelated conditions of density, proximity, and mix within the urban fabric (Jacobs, 1961). This research takes these conditions as its point of departure and examines them through retail patterns. Urban vitality is operationalized here as the intensity, concentration, and variety of retail activity, measured respectively as retail density, agglomeration, and diversity, consistent with studies that measure the vitality of commercial streets through the density and diversity of activities (Jacobs, 1961; Guo et al. 2021; Mohamed & Allani, 2025). Retail is not the only expression of vitality, but it is particularly relevant in peripheral areas, where cultural and civic functions are often scarce and retail clusters act as the principal settings of everyday encounter and exchange, forming emerging subcenters within decentralized urban fabrics (Oswald & Scholl, 2001). Retail activity can also be measured consistently across cities, allowing the conditions of vitality to be compared between contexts. Retail centrality, in turn, refers to the capacity of a location to concentrate retail activity, observable through these three metrics.

The spatial pattern of retail units has largely been discussed through economic and functional perspectives that consider space as a passive container, leaving the morphological structure of cities, particularly at the plot scale, underexplored. This has produced a persistent divide between retail geography and urban morphology as fields of inquiry (Araldi et al., 2024), limiting the understanding of how urban form relates to the conditions for vitality in the retail landscape. The intensity and diversity of retail activity, central to Jacobs's account of urban vitality, are

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not simply outcomes of market forces or functional zoning but are associated with the morphological structure of the urban fabric. This association is examined here at the plot scale, where two dimensions of urban form intersect: compositional attributes, the structural properties of individual plots such as size, coverage, and frontage; and configurational attributes, the relational position of plots within the street network, capturing accessibility and connectivity (Marshall, 2004; Efeoglu et al., 2025).

Contemporary planning practice has increasingly deemphasized the plot as a fundamental unit of urban development, favoring streets, urban blocks, and buildings (Love & Crawford, 2011; Porta & Romice, 2010; Panerai et al., 2004). This gap is particularly relevant in peripheral urban areas, where retail development increasingly concentrates in emerging subcenters characterized by large-scale plot development and car-oriented infrastructure. Unlike city centers, where street-based retail morphology has been more extensively discussed (Porta et al., 2012; Scoppa & Peponis, 2015; Bobkova et al., 2019), peripheral retail clusters exhibit greater morphological heterogeneity and are more exposed to standardized development patterns that may weaken the plot-scale conditions associated with retail vitality. For planners, an analytical tool that relates plot-level morphological attributes to retail patterns can therefore provide a more spatially grounded basis for decisions in these areas.

Existing approaches address parts of this relationship. Plot-based urbanism focuses on the compositional structure of plot systems (Porta & Romice, 2010; Bobkova et al., 2021), space syntax measures the configurational position of streets (Penn & Turner, 2004; Scoppa & Peponis, 2015), the node-place model evaluates the balance between accessibility and activity around transport nodes (Bertolini, 1998), and retail geography examines the location of retail in relation to street-based or economic factors (Sevtsuk, 2014; Araldi & Fusco, 2019). What remains missing is a plot-scale framework that examines compositional and configurational attributes together and identifies which of them corresponds with each component of retail vitality in a given context. To address this, the research proposes a Morphological Assessment Framework (MAF). The MAF weights plot-level compositional and configurational attributes according to their spatially varying associations with each retail metric, enabling researchers to identify which morphological dimension, and which of its attributes, carries retail density, agglomeration, and diversity in a given urban context, and to locate the plots that fall short of these conditions. The research addresses the following questions: (i) How are compositional and configurational plot attributes associated with retail density, agglomeration, and diversity in peripheral areas, and how do these associations differ across urban contexts? (ii) Do these morphological characteristics correspond with the spatial form of retail clusters? Rather than seeking causal relationships, the research interprets spatial associations within a relational morphological framework, using peripheral retail clusters in Ankara (Türkiye), Helsinki (Finland), and Vilnius (Lithuania) as comparative cases with contrasting development models.

2. Background

Following the Netzstadt model, the city is understood as a network of links, fields, and nodes, with retail acting as an activator of nodal strength (Oswald & Scholl, 2001). In contemporary cities, decentralized urban fabrics generate new nodes, and retail converts them into spatial focal points. Retail centrality can therefore be understood as a location's capacity to transform movement flows into encounters, exchanges, and diverse activities, an outcome of spatial relations rather than a fixed category (Castells, 1977; Joutsiniemi, 2010). The node-place model (Bertolini, 1998) offers a relational framework for interpreting such dynamics by distinguishing between node value (connectivity within wider transport networks) and place value (the intensity and diversity of local activities), with balanced centrality associated with the two reinforcing each other. This research draws on this relational logic to examine how compositional and configurational attributes of plots are associated with retail centrality and explores whether these associations correspond with different retail cluster forms.

Discussions of retail spatiality have long been shaped by economic location theories that treat urban space primarily as a container for economic activity (Davies, 1968; Saraiva & Pinho, 2017). A growing body of literature has since challenged this view, showing that retail patterns are associated with the morphological structure of cities (Porta et al., 2012; Bobkova et al., 2019; Sevtsuk, 2020; Efeoglu et al., 2024). Marcus (2026) provides a theoretical basis for this shift through spatial capital theory, which identifies distance, density, and differentiation as the primary dimensions through which built form structures urban activity. Distance relates to street network configuration, density to the intensity of built form at each location, and differentiation to land subdivision into discrete plots under independent ownership. In this research, distance and differentiation correspond to the configurational dimension of plots and density to the compositional dimension.

On the configurational side, retail activity tends to concentrate in well-integrated areas of the street network, which have been associated with movement patterns and commercial performance (Porta et al., 2012; Scoppa & Peponis, 2015; Penn & Turner, 2004). Street centrality measures, particularly integration and betweenness, relate to the location of retail businesses across diverse contexts (Wang et al., 2014; Han et al., 2019), consistent with the conditions for pedestrian encounter that Jacobs identified as foundational to urban vitality. On the compositional side, fine-grained plots and small frontages are associated with the clustering of retail uses and street-based commercial activity (Joosten & van Nes, 2005; Bobkova et al., 2019), while larger plots with wide frontages tend to coincide with discontinuous environments and car-oriented retail formats (Hausleitner & Berghauser Pont, 2017; Efeoglu et al., 2024). Plot size, ground area ratio, and frontage conditions have been linked to retail density and diversity at the neighborhood scale (Marcus, 2010; Sevtsuk, 2020), and store size and street accessibility have been

associated with commercial performance in self-organized mixed-use neighborhoods (Mishra & Roy, 2024). Marcus (2026) further argues that differentiation, operationalized through plot subdivision, is the primary spatial mechanism enabling categorical diversity of urban activity, since each independently governed plot opens the possibility for a different actor and use.

Marcus (2026) also conceives markets as co-presences of people and things structured by the combined operation of distance, density, and differentiation. Following this perspective, this research proposes that where compositional and configurational attributes of urban form align, urban spaces are more likely to sustain the intensity and diversity of economic and social interaction, made visible through patterns of retail density, agglomeration, and diversity. Retail centrality may therefore relate to how these dimensions combine rather than to either alone. However, the two dimensions have mostly been studied in isolation (Araldi & Fusco, 2019), limiting a relational understanding of how they jointly relate to retail outcomes. Examining them together offers a way of connecting retail geography and urban morphology, and of making the conditions of urban vitality spatially legible at the plot scale.

3. Methodology

Ankara, Helsinki, and Vilnius were selected as capital cities with comparable roles as the primary retail and administrative centers of their countries, but with different retail development models and peripheral morphologies. These differences, reflected in retail growth, market concentration, and enterprise size (Supplementary Material, Table S1), distinguish market-driven expansion along arterial corridors in Ankara, a regulated retail market organized in planned centers on large suburban plots in Helsinki, and a post-socialist transition towards larger retail formats within Soviet-era housing estates in Vilnius. The study areas comprise the Helsinki Metropolitan Area, the Vilnius City Municipality, and the Çankaya district of Ankara, which contains both the city's central business district and a major peripheral development zone along its southwestern corridor, thereby covering the full central–peripheral gradient.

Peripheral retail clusters were defined through three locational attributes applied uniformly across the three cities: network distance to the central business district, population density, and the number of retail units. These were combined into an index in which clusters located farther from the CBD, in areas of lower population density, and with higher retail concentrations receive higher values (Step 1; Table S3); because the index is measured relative to the CBD and normalized within each study area, the selection does not depend on the differing sizes of the study areas. The selection aims to test whether the associations between plot morphology and retail outcomes yield meaningful and differentiated results across structurally diverse environments, rather than being specific to a single context. Institutional and planning contexts are treated as interpretive background rather than explanatory variables, because comparable plot-level measures of zoning, ownership, and regulation were not available across the three national contexts; their potential influence on the observed patterns is considered in the Discussion.

To examine how compositional and configurational attributes relate to retail patterns and cluster forms, this research develops the Morphological Assessment Framework (MAF), which takes the plot as the unit of analysis, capturing both its structural properties and its relational position within the street network. The MAF is operationalized in five steps:

Step 1: identification and selection of retail clusters

Retail clusters were identified using density-based spatial clustering (DBSCAN) applied to the point distribution of retail units, with a minimum of five retail units per neighborhood (minPts = 5); only clusters containing more than 10 retail units were retained, so that the analysis focuses on substantial retail concentrations. The neighborhood radius (ε) was determined for each city from its k-distance graph; the parameter selection procedure and a sensitivity analysis across alternative thresholds are reported in the Supplementary Material (Figure S1, Table S2). Following cluster identification, three locational attributes, namely population density, network distance to the central business district, and number of retail units, were calculated for each cluster and applied uniformly across all study areas. These attributes were normalized and combined into an index identifying peripheral retail concentrations (Table S3). Clusters with a combined index value above 0.75, that is, in the upper quarter of the normalized index range, were retained for further analysis. This threshold selects clusters that are simultaneously distant from the CBD, located in areas of low population density, and characterized by high numbers of retail units, rather than peripheral on only one criterion; because the index is normalized within each city, the peripheral retail concentrations are selected on a comparable relative basis, while the number of clusters remains suitable for detailed plot-level analysis.

Step 2: delineation of retail cluster boundaries

The spatial extent of each selected retail cluster was delineated following the spatial monopoly (deterministic) approach to trade area delimitation, in which trade areas are defined by a travel distance with definite boundaries (Jones & Simmons, 1993). A 500-meter network-based walking catchment was calculated for each retail unit within the cluster, extending slightly beyond the 400-meter radius used for the local metrics, so that plots at the edge of each cluster are measured with their full surroundings; this helps to mitigate edge effects when measuring the contextual features of plots (Gil, 2017). The plots accessible within this distance define the boundary of each analyzed cluster.

Step 3: measurement of morphological and retail metrics

Morphological and retail metrics were measured for all plots within the delineated cluster boundaries. On the

morphological side, both compositional and configurational attributes were computed for each plot (Table 1). Compositional attributes, plot area, ground area ratio, building frontage ratio, and plot frontage ratio capture the structural properties of individual plots and their relation to spatial capacity and economic specialization (Marcus, 2010; Webster & Lai, 2005; Sevtsuk, 2014). Smaller plot frontages have been associated with social interaction and retail density (Thwaites et al., 2020; Bobkova et al., 2019), while building frontages offer the potential to link retail activity to the social vitality of the street, revealing how spatial layout may support or constrain retail presence (Kickert, 2016; Abdulmawla et al., 2022). It is suggested that typo-morphological and configurational approaches can be effectively combined through network structures and elements of the urban fabric such as plots (Kropf, 2017), thereby enabling a deeper understanding of urban form by correlating spatial patterns of retail distribution with the compositional and configurational morphology of plots. Configurational attributes, global and local angular integration, node connectivity, and plot frequency, capture each plot's relational position within the street network. Integration reflects spatial centrality favorable to retail presence (Porta et al., 2012; Wang et al., 2014; Paroli & Maraschin, 2018), plot frequency indicates land subdivision intensity and differentiation linked to functional diversity and social vitality (Marcus, 2010, 2026; Hausleitner & Berghauser Pont, 2017; Araldi, 2019), and node connectivity reflects spatial permeability and accessibility (Ewing & Cervero, 2010). Configurational measures of network structure were translated to the plot level, which served as the unit of analysis, using the Place Syntax Tool within a 400-meter walking distance threshold, corresponding to an approximately five-minute walk commonly used to define local pedestrian accessibility (Duany et al. 2000; Efeoglu et al. 2024).

Three retail metrics were computed as dependent variables (Table 2). Retail density measures the ratio of retail units to normalized plot area. Retail agglomeration measures the ratio of retail units within a 400-meter radius to those within a 1000-meter radius from the origin plot, comparing the five-minute walking catchment of a plot with its wider neighborhood (Araldi & Fusco, 2019; Efeoglu et al., 2024). Retail diversity is measured as the variety of retail types within 400 meters of the origin plot using the Shannon Diversity Index.

The data were obtained from multiple sources (Table S10). Building data for the Helsinki Metropolitan Area (HMA) were retrieved from the Helsinki Region Environmental Services Authority's open map service. Plot boundaries were obtained from the municipalities' open map services in the HMA and from the Spatial Information Portal of Lithuania for Vilnius. Ankara data were sourced from the Maps and Plans Documentation Unit of METU Faculty of Architecture. Retail units were compiled as geolocated Points of Interest from Google Maps Platform

Table 1. Independent variables: compositional and configurational morphological metrics

	Name	Definition	Equation	
Compositional Morphological Attributes of Plot	Plot Area (PA)	The area of a plot	$PA = Pa_j$	where Pa is the area of plot j.
	Ground Area Ratio (GAR)	The ratio between the footprint area of the buildings and the plot area	$GAR = \frac{^{W} B_j}{Pa_j}$	where B is the total ground area of buildings located within the plot j, and Pa is the area of plot j.
	Building Frontage Ratio (BF)	The ratio between the building street boundary and the perimeter of the building	$BF_p = \frac{1}{n_p} \sum_{j \in B(p)} \frac{Bf_i}{Bp_j}$	Where Bf_i is the street-facing boundary length of building j. Bp_j is the perimeter of building j, and n_p is the number of buildings in plot p.
	Plot Frontage Ratio (PF)	The ratio between the plot street boundary and the perimeter of the plot	$PF = \frac{Pf_j}{Pp_j}$	where Pf is the length of the street boundary of plot j, and Pp is the perimeter of plot j.
Configurational Morphological Attributes of Plot	Global and Local Angular Integrations of Plot (AI)	The average of the integration value of road segments that can be reached within a certain distance from the origin plot	$AI_o = \frac{\sum_{a \in A(o;D)} f(a)}{N_{(o;D)}}$	where o is the origin plot, a is the attraction that is the integration value of each road segment, D is the distance threshold (set at n for Global Integration; set at 400m for Local Integration), $N(o; D)$ is the set of reachable attractions within the given distance, $f(a)$ is the attraction value.
	Local Node Connectivity of Plot (NC)	The number of nodes (road intersections) that can be reached within a certain distance from the origin plot	$NC_o = \sum_{n \in N(o;D)} 1$	where o is the origin plot, n is a node, D is the distance threshold (set at 400m), $N(o; D)$ is the set of nodes reachable from plot o within distance D.
	Plot Frequency (PFr)	The total number of accessible plots within the given distance from the origin plot	$PFr_o = \sum_{e \in A(o;D)} f(e)$	Where o is the origin plot, e is the attraction that is the number of plots, D is the distance threshold (set at 400m), $A(o; D)$ is the set of reachable attractions within the given distance, $f(e)$ is the attraction value.

Table 2. Dependent variables: retail metrics

Name	Definition	Equation	
Retail Density (RD)	The ratio of the number of retail units to normalized plot area	$RD_o = \sum R_o \Big/ \frac{(Pa_o - Pa_{\min})}{(Pa_{\max} - Pa_{\min})}$	where R is the number of retail units on plot o, Pa is the area of the plot o, $Pa_{\min}$ is the area of the smallest plot, $Pa_{\max}$ is the area of the largest plot.
Retail Agglomeration (RA)	The ratio of retail unit numbers within a 400m/1000m radius from the origin plot	$RA_o = \sum_{d_{oj}<r_1} D_j \Big/ \sum_{d_{oj}<r_2} D_j$	where o is the origin plot, D is the number of retail stores on plot j, d_{oj} is the distance between the origin plot and every other plot, r_1 is the 400 m radius from the origin plot; r_2 is the 1000 m radius from the origin plot.
Retail Diversity (DV)	The retail unit variety within a 400m radius of the origin plot	$DV_o = \sum_{i \in A(o;D)} p_i * \ln(p_i) * (-1)$	where o is the origin plot, D is the distance threshold (set to 400m), i is the type of retail business, p is the proportion of each type of retail business, $\ln(p_i)$ is the natural log of the proportion (Shannon Diversity Index).

and OpenStreetMap, cross-checked and cleaned to ensure spatial accuracy. The cleaning and classification procedure is reported in the Supplementary Material (Table S4). Individual retail establishments within large complexes such as shopping malls were represented as separate units, as each represents an independent retail activity; aggregating them would underestimate retail density and diversity and treat mall and street-based retail inconsistently. Businesses were classified into seven categories based on Sections G47 and I56 of the European Classification of Economic Activities (Eurostat, 2008).

Step 4: regression analysis and morphological indicators

Multiscale Geographically Weighted Regression (MGWR) was used to examine how associations between morphological indicators and retail metrics vary spatially across different contexts. Associations between morphology and retail activity are not spatially uniform, the same plot-level indicator may be associated differently with retail outcomes across locations within and between cities. By allowing each predictor to operate at its own spatial scale, MGWR provides a more flexible framework than traditional global regression or single-scale GWR models (Fotheringham et al., 2017; Table S9). Local coefficients were derived for each independent variable with respect to each retail metric in each study area, indicating the direction and strength of the association at the local level. Only statistically significant local coefficients were retained for the subsequent stage.

Using these coefficients, compositional and configurational indicators were then calculated for each plot. Morphological variable values were weighted by the corresponding average MGWR coefficient derived from statistically significant local coefficients for each retail metric. Variables were standardized within each city prior to weighting, consistent with the standardized specification of the MGWR models. The compositional indicator was calculated from plot area, ground area ratio, building frontage ratio, and plot frontage ratio. The configurational indicator was calculated from plot frequency, node connectivity, local integration, and global integration (Table S5). Because the weights are recalibrated for each city, the indicators capture context-specific morphological–retail associations rather than fixed global effects.

Step 5: analysis of morphological character and retail cluster form

In the final step, the morphological character of plots was related to retail patterns and to the form of retail clusters. First, the correlations between the weighted compositional and configurational indicators of plots and retail density, agglomeration, and diversity were examined for each city and for all plots combined, using Pearson's correlation coefficient. Effect sizes were interpreted following Cohen (1988): |r| < 0.10 negligible, 0.10–0.29 weak, 0.30–0.49 moderate, and ≥ 0.50 strong. The correlation between the two indicators was also examined to assess whether the compositional and configurational dimensions operate in opposition at the plot level (Table S12). Because plots are nested within retail clusters, observations within the same cluster are not fully independent. The plot-level associations were therefore additionally tested using linear mixed-effects models with a random intercept for cluster and city as a fixed effect (Table S13).

Second, to examine the relationship between morphological characteristics and cluster form, a shape index was derived from standard deviational ellipses computed for each selected cluster (Table S3). Standard deviational ellipses summarize the dispersion and directional orientation of point patterns (Yuill, 1971), capturing both the spatial extent and dominant orientation of retail units. The shape index relates the ellipse area to its perimeter, providing a normalized measure of cluster geometry: values close to one indicate compact formations, while lower values indicate more elongated, corridor-like configurations. Shape indices were first compared across the three cities. Because the shape index is defined at the cluster level, its association with morphological character was then assessed with clusters as the unit of analysis (n = 19), relating the median compositional and configurational indicators of each cluster to its shape index. Given the small number of clusters, Spearman's rank correlations were used, with bootstrap 95% confidence intervals (5000 resamples) and permutation-based p-values (10000 permutations) (Table S11).

4. Findings

The k-distance analysis yielded city-specific thresholds of 120 m for Ankara, 200 m for Helsinki, and 216 m for Vilnius (Figure S1). Applying DBSCAN with these thresholds produced 94 retail clusters in Ankara, 58 in Helsinki, and 49 in Vilnius (Figure 1), while isolated retail units remained unclustered.

Following the calculation of the combined index uniting population density, distance to the central business district, and number of retail units, clusters with an index value above 0.75 were selected for analysis, yielding 7 peripheral retail clusters in Ankara, 5 in Helsinki, and 7 in Vilnius (Figure 2). Applying the 500-meter network-based walking catchment to delineate the spatial boundaries of each selected cluster, 3402 plots were identified in Ankara, 613 in Helsinki, and 1049 in Vilnius, resulting in a total of 5064 plots across all three cities for subsequent analysis (Figure 3).

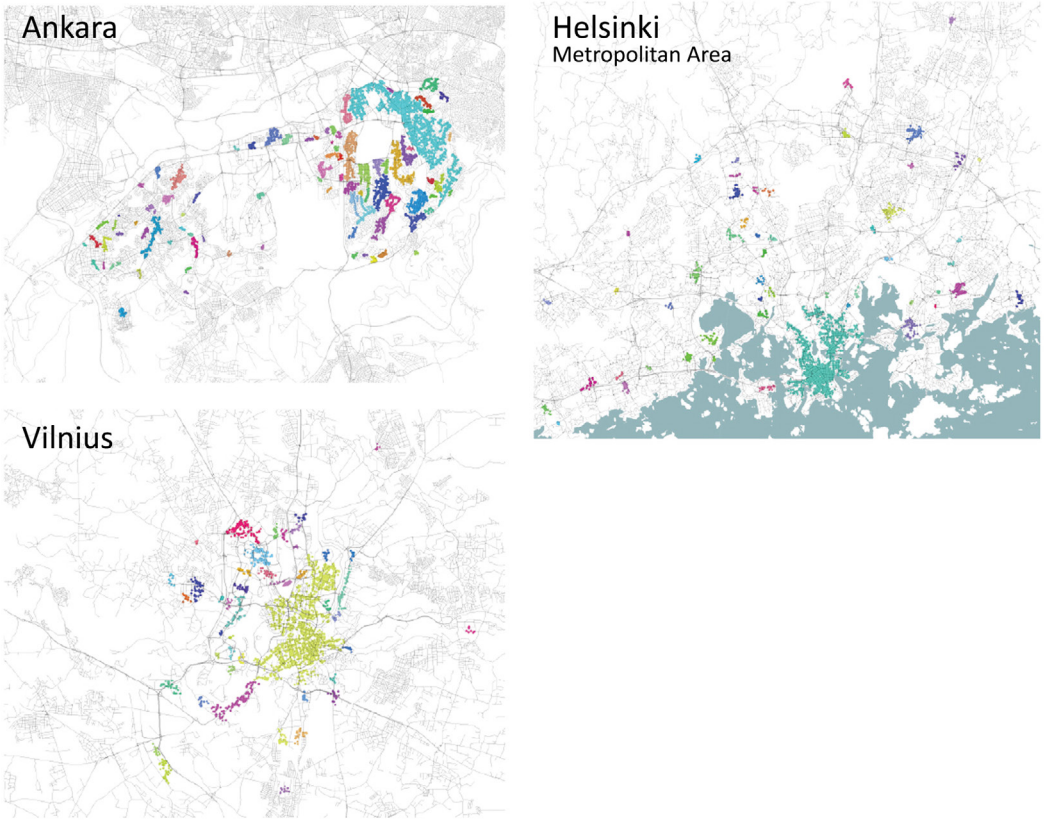


Figure 1. Identified retail clusters derived from DBSCAN (colors indicate different clusters and are arbitrary)

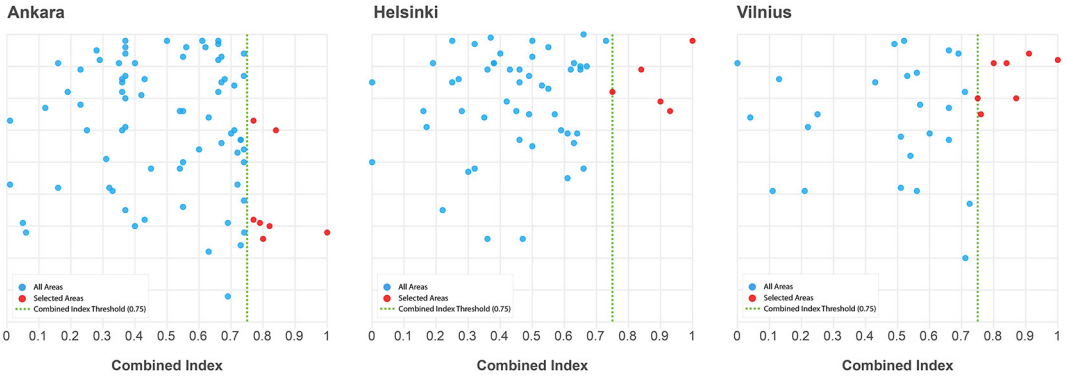


Figure 2. Selected retail clusters in each city based on the combined index

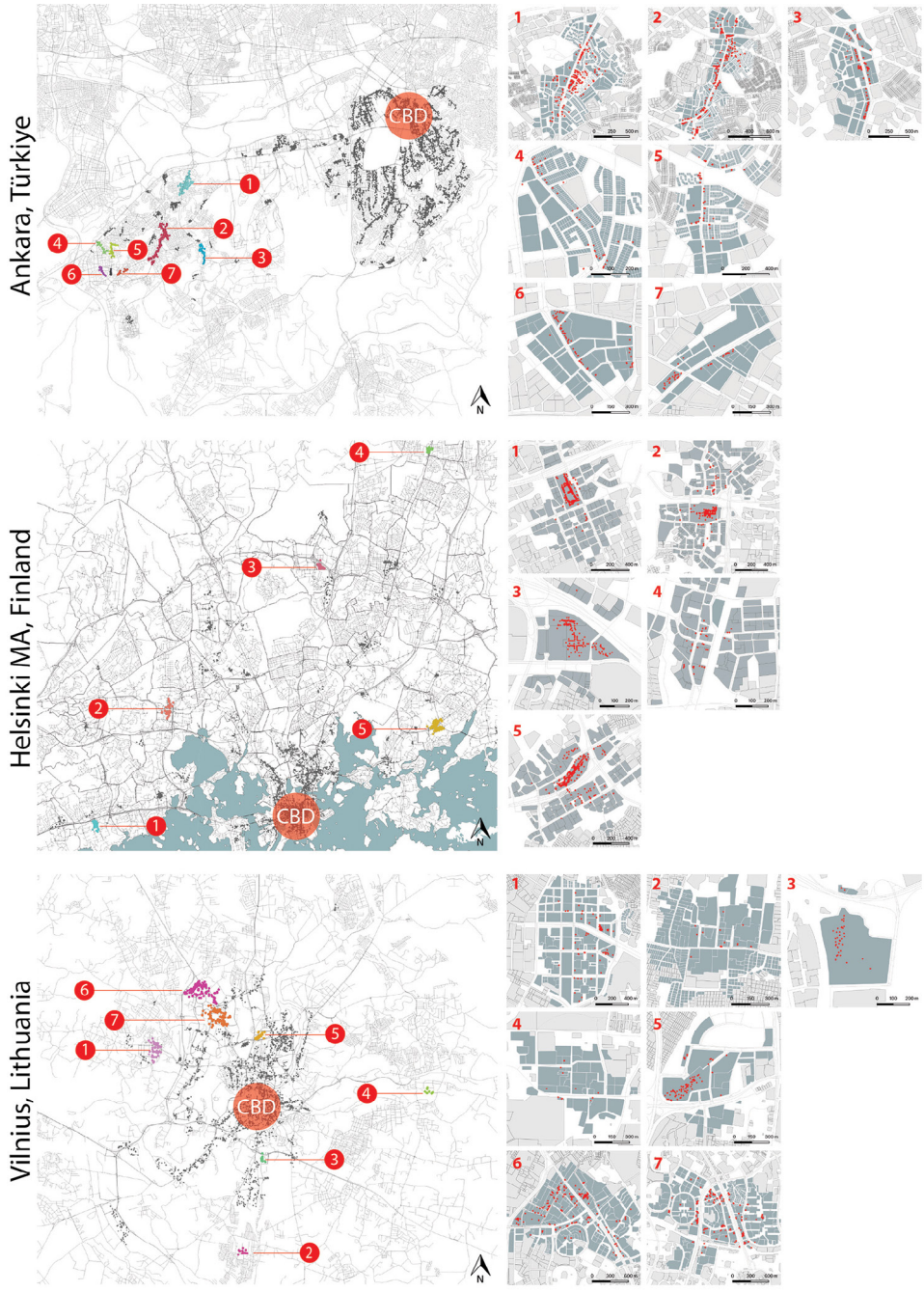


Figure 3. Selected retail clusters in each city and plots within 500m of retail units

4.1. Local coefficients of morphological variables on retail metrics

The relationships between morphological variables and retail density, agglomeration, and diversity were determined using the mean of statistically significant local MGWR coefficients (Figure 4, Tables S6–S8).

Retail density is highest in Helsinki (1.0), followed by Vilnius (0.2) and Ankara (0.05) (Figure 5). In Ankara, density is associated with configurational variables, global integration and plot frequency, suggesting retail concentration along highly integrated routes. In Helsinki, density is associated with compositional attributes, including larger plot areas and higher ground-area ratios, reflecting intensive retail development within individual plots and building complexes. Vilnius shows an intermediate pattern in which local connectivity is associated with higher plot-level density, while larger and more integrated plots correspond with more dispersed retail activity.

Retail agglomeration shows a clear hierarchy: Ankara exhibits the strongest clustering (1.0), Vilnius moderate levels (0.7), and Helsinki very weak agglomeration (0.05) (Figure 5). In Ankara, agglomeration corresponds most strongly with node connectivity, followed by plot frequency and global integration, while larger plot areas are associated with lower agglomeration. In Helsinki, agglomeration

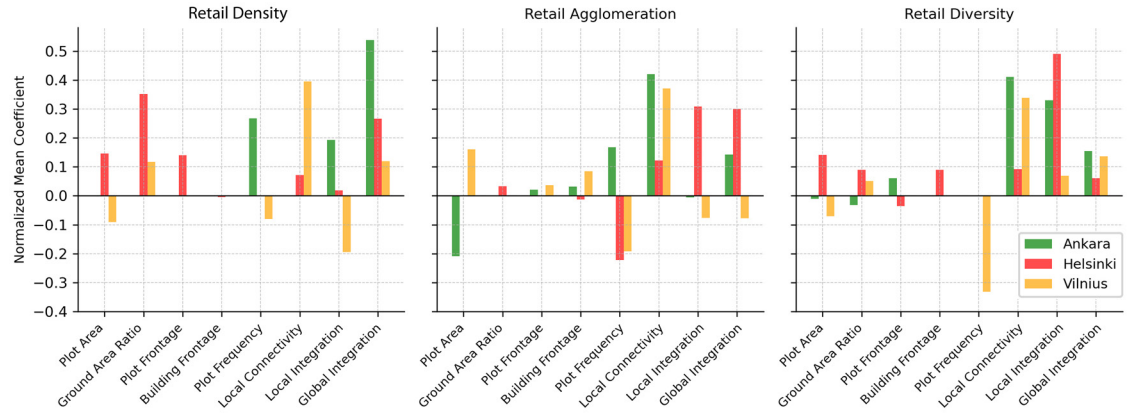


Figure 4. Associations between morphological variables and retail metrics for each city (mean significant local MGWR coefficients)

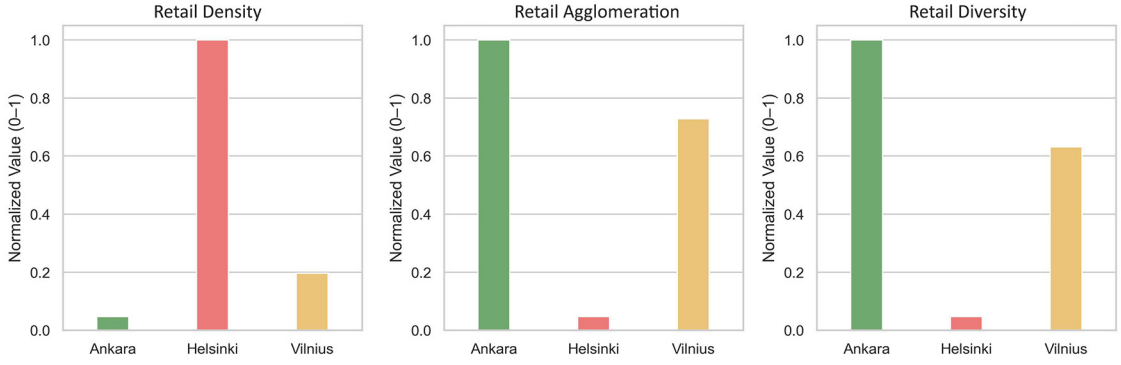


Figure 5. The mean values of retail density, agglomeration and diversity for each city

is associated with local and global integration, whereas higher plot frequency corresponds with lower agglomeration, and compositional variables show only weak associations. Vilnius shows moderate clustering, with large plots with wide frontages and strong local connectivity corresponding to retail concentrations.

Retail diversity follows a similar pattern, with Ankara exhibiting the highest normalized level (1.0), followed by Vilnius (0.63) and Helsinki (0.05) (Figure 5). In Ankara, diversity is associated with node connectivity and local integration, and to a lesser extent with building frontage. In Helsinki, diversity corresponds primarily with local integration and secondarily with larger plot areas. Vilnius again shows an intermediate pattern where plot connectivity coincides with functional variety.

These city-specific patterns provide the basis for the joint analysis that follows, which examines how the combined compositional and configurational character of plots relates to retail outcomes.

4.2. Morphological characters associated with retail patterns

Building on the individual variable associations identified above, the MAF examines how compositional and configurational attributes jointly characterize the morphological conditions of plots in relation to retail patterns. By plotting the weighted indicators along compositional (horizontal) and configurational (vertical) axes, four morphological conditions can be distinguished: high on both dimensions (Q1); low on the compositional but high on the configurational dimension (Q2); low on both dimensions (Q3); and high on the compositional but low on the configurational dimension (Q4). Because the indicators are based on within-city standardized variables, 0 corresponds to the city mean, and positive values indicate conditions more favorable than the city average for the given retail metric. The position of plots within these quadrants reveals whether retail outcomes are more strongly associated with structural capacity, network context, or their combination. The extent to which a city's distribution spreads along each axis indicates which dimension carries the morphological–retail association in that context. Associations are reported for each city and for all plots combined (Tables 3–5).

In terms of *retail density*, the three cities display distinct distributions in the MAF (Figure 6). In Ankara, where no compositional variable had a significant local coefficient, plots are distributed along the configurational axis only, indicating that variation in retail density is associated with network position rather than with plot-level structural capacity. Helsinki displays a predominantly horizontal dispersion, with plots of higher retail density extending

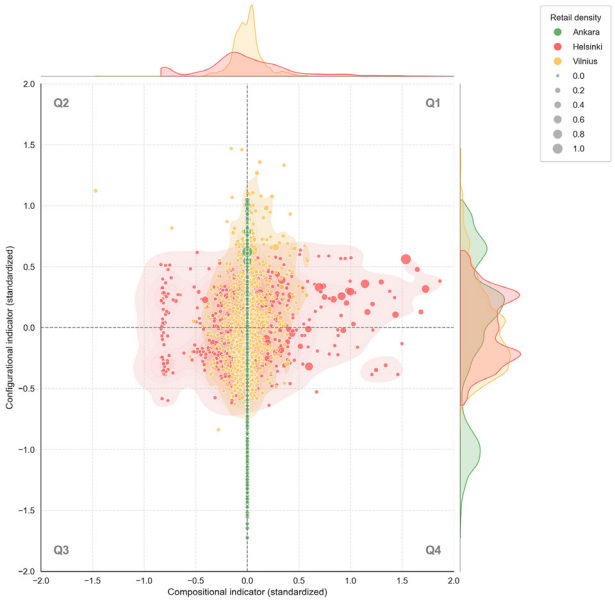


Figure 6. MAF for retail density: compositional and configurational indicators of each plot. Indicators are sums of within-city standardized morphological variables weighted by their mean significant MGWR coefficients; 0 corresponds to the city mean (point size indicates retail density)

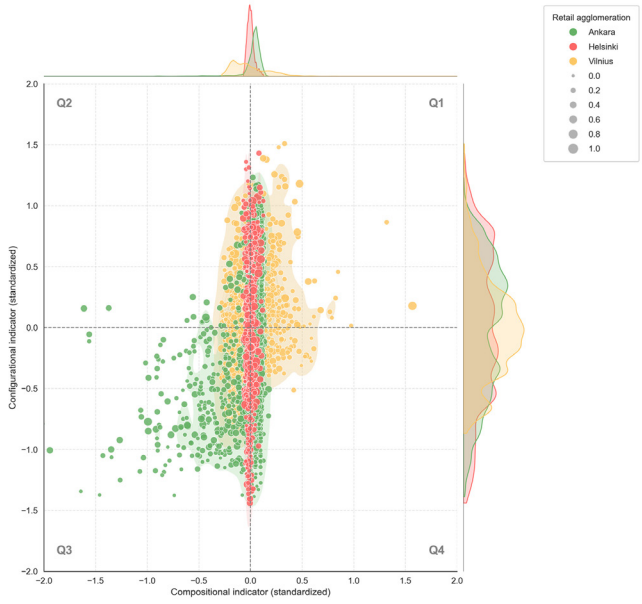


Figure 7. MAF for retail agglomeration: compositional and configurational indicators of each plot (point size indicates retail agglomeration)

towards the positive compositional range, suggesting that retail densification corresponds with intrinsic plot attributes even where network integration is limited. Vilnius displays a narrow distribution along the compositional axis, with greater variation along the configurational axis.

Table 3. Correlation of morphological indicators with retail density (Pearson r)

	All plots	Ankara	Helsinki	Vilnius
Compositional character – retail density	0.37*	–	0.46*	0.13*
Configurational character – retail density	0.05*	0.06*	0.09*	0.16*

Note: *$p < 0.05$ (No compositional variable had a statistically significant local coefficient for retail density in Ankara).

The correlation results (Table 3) are consistent with these patterns. The compositional indicator shows a moderate positive association in Helsinki (0.46) and a weak positive association in Vilnius (0.13), indicating that higher plot-level structural capacity corresponds with higher retail density. In Ankara, retail density shows a negligible positive association with configurational character (0.06). Configurational associations with density are weak in Helsinki and Vilnius (0.09 and 0.16). Across all plots, density is moderately associated with compositional character (0.37) and negligibly with configurational character (0.05) (Table 3).

In terms of retail agglomeration, Helsinki displays a narrow distribution along the compositional axis that extends predominantly along the configurational axis, with plots of higher agglomeration not concentrated at higher configurational values (Figure 7). In Ankara and Vilnius, the distributions extend along both axes; in Ankara, plots spread diagonally towards negative values on both dimensions (Q3), reflecting the positive association between the two indicators (Table S12), while in Vilnius plots with higher agglomeration tend to occupy the upper range of the configurational axis.

Table 4. Correlation of morphological indicators with retail agglomeration (Pearson r)

	All plots	Ankara	Helsinki	Vilnius
Compositional character – retail agglomeration	0.08*	0.06*	0.17*	0.13*
Configurational character – retail agglomeration	0.16*	0.21*	–0.05	0.27*

Note: *$p < 0.05$.

Configurational character is weakly positively associated with agglomeration in Ankara (0.21) and Vilnius (0.27), while in Helsinki the association is not significant (−0.05). In Helsinki, agglomeration instead corresponds weakly with compositional character (0.17), consistent with retail activity concentrating within plots of higher structural capacity rather than forming multi-plot street clusters. Compositional associations in Ankara and Vilnius are negligible to weak (0.06 and 0.13). Across all plots, agglomeration is weakly associated with configurational character (0.16) and negligibly with compositional character (0.08) (Table 4).

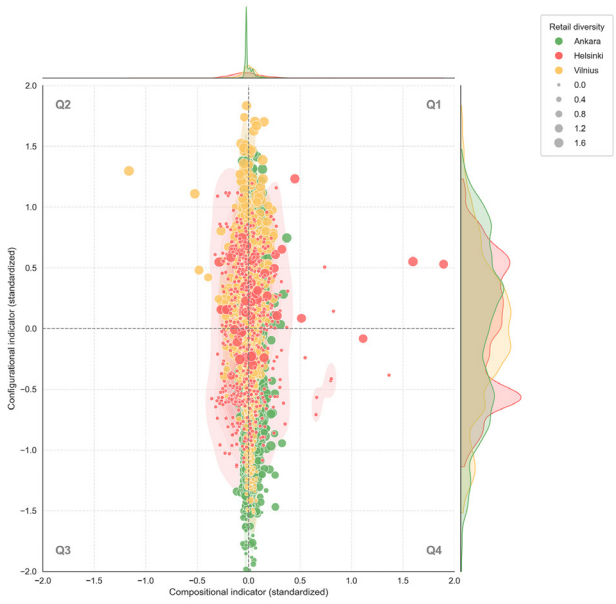


Figure 8. MAF for retail diversity: compositional and configurational indicators of each plot (point size indicates retail diversity)

In terms of *retail diversity*, the three cities again display predominantly vertical distributions (Figure 8), with plots of higher diversity concentrated towards the upper range of the configurational axis, most visibly in Vilnius. Helsinki shows a somewhat wider dispersion along the compositional axis, but higher diversity values are not clearly associated with either direction of that dispersion.

Table 5. Correlation of morphological indicators with retail diversity (Pearson r)

	All plots	Ankara	Helsinki	Vilnius
Compositional character – retail diversity	0.01	–0.08*	0.16*	–0.01
Configurational character – retail diversity	0.31*	0.40*	0.13*	0.60*

Note: *$p < 0.05$.

The correlation results (Table 5) indicate that diversity is the retail metric most consistently associated with configurational character, which shows a positive association in all three cities: strong in Vilnius (0.60), moderate in Ankara (0.40) and weak in Helsinki (0.13). Compositional associations are weak or negligible and vary in direction: weakly positive in Helsinki (0.16), negligibly negative in Ankara (−0.08), and not significant in Vilnius. Across all plots, diversity is moderately associated with configurational character (0.31), while the compositional association is not significant (0.01). These results indicate that retail diversity corresponds primarily with the network position of plots rather than with their structural capacity.

These results indicate that the three retail metrics correspond with different morphological dimensions of the plot. Retail density is associated primarily with compositional character, most clearly in Helsinki, whereas retail agglomeration and, more consistently, retail diversity are associated primarily with configurational character; diversity shows the most robust pattern, with a positive configurational association in all three cities. The cities differ, however, in which dimension carries these associations: Ankara displays a configuration-led condition, Helsinki a composition-led condition, and Vilnius an intermediate condition in which both dimensions contribute within narrower ranges.

These conditions are also reflected in the spatial form of retail clusters. Clusters in the configuration-led context of Ankara are elongated, following major routes (shape index 0.35–0.73), whereas those in the composition-led and mixed contexts of Helsinki and Vilnius are compact (0.76–0.98 and 0.80–0.98). This correspondence is expressed between cities rather than between individual clusters, as cluster form shows no significant association with the morphological character of plots at the cluster level (Table S11), suggesting that the form of retail clusters reflects the broader morphological context of each city rather than the plot-level conditions within each cluster. Within cities, the compositional and configurational indicators are weakly positively associated or unrelated (Table S12), indicating that the two dimensions are not in opposition at the plot level but contribute differently to retail patterns depending on context. The associations between the morphological indicators and the retail metrics (Tables 3–5) remained statistically significant when the nesting of plots within clusters was accounted for in mixed-effects models (Table S13).

5. Discussion

This section interprets the context-specific patterns identified by the MAF, considers why the contexts differ, and outlines implications for retail vitality in peripheral areas.

5.1. Context-specific morphological conditions

The three cities display distinct morphological conditions: configuration-led in Ankara, where no compositional variable showed a significant association with retail density; composition-led in Helsinki, where retail is concentrated within large plots and complexes; and intermediate in Vilnius. These conditions are mirrored in cluster form, which is elongated and corridor-like in Ankara and compact and node-like in Helsinki and Vilnius.

These differences are consistent with the development contexts of the three cities (see Supplementary Material). In Ankara, market-led development and the absence of a coherent retail policy have favored commercial activity along the most accessible roads (Erkip & Özüduru, 2015). In Helsinki, strict land-use control and post-1950s suburban expansion based on large plots have concentrated retail within planned, often transit-oriented nodes (Efeoglu et al., 2024). In Vilnius, the post-socialist estate fabric, where micro-businesses frequently occupy the

ground floors of residential buildings, combines moderate plot capacity with locally connected street networks. As institutional and planning contexts were not included as explanatory variables, these interpretations remain contextual rather than tested.

Within each city, compositional and configurational attributes are positively associated or unrelated (Table S12). The two dimensions are therefore complementary rather than opposed, and their relative weight differs between contexts. Plots combining structural capacity with strong network integration may thus support retail density, agglomeration, and diversity simultaneously. In peripheral contexts dominated by block-based development (Love & Crawford, 2011; Porta & Romice, 2010), such combinations may appear less frequently, suggesting that the de-emphasis of the plot as a unit of development may limit the conditions under which these retail patterns coexist. Peripheral retail vitality may therefore depend on the combination of both dimensions rather than on either alone.

5.2. Vitality of retail landscape as a morphological outcome

Retail density, agglomeration, and diversity each correspond with a different morphological dimension, indicating that retail vitality is not a unitary condition but a differentiated outcome. Treating these metrics separately allows the intensity, concentration, and variety of retail activity, conditions Jacobs (1961) identified as interrelated, to be related to distinct dimensions of urban form.

Retail density tends to be highest where compositional capacity is strong, as larger plots, higher ground area ratios, and wider frontages provide space for concentrated retail development, most clearly in Helsinki and, to a lesser extent, Vilnius. Compositional capacity is not, however, consistently associated with retail diversity, being weakly positive in Helsinki, negligibly negative in Ankara, and not significant in Vilnius. Plot capacity thus appears to accommodate the concentration of retail activity without corresponding with its variety, consistent with research indicating that large-grain plots favor retail concentration and single-occupier formats over the diversity of independent micro-businesses (Marcus, 2010; Hausleitner & Berghauser Pont, 2017; Sevtsuk, 2020; Efeoglu et al., 2024).

Retail agglomeration is associated primarily with configurational character in Ankara and Vilnius. In Helsinki, it corresponds instead with compositional character, reflecting retail concentration within individual plots and complexes rather than across multiple plots along streets. Agglomeration may therefore take two morphological forms, network-based clustering across plots and plot-based concentration within large complexes, which the MAF can distinguish.

Retail diversity shows the most consistent pattern, with a positive configurational association in all three cities, indicating that the variety of retail activity corresponds with network position more than with physical plot attributes. This is consistent with the view that well-integrated locations offer the movement potential needed to sustain a wider range of retail functions (Porta et al., 2012; Sevtsuk, 2020). The role of individual attributes is not uniform, however. Marcus (2026) argues that plot differentiation, the number of plots accessible through the street network, supports diversity in urban activity. Plot frequency, which operationalizes differentiation, is negatively associated with retail diversity in Vilnius and negligibly elsewhere, while the combined configurational character is positively associated with diversity in all three cities. Differentiation may therefore translate into retail variety only where sufficient network integration sustains independent retailers, suggesting that differentiation alone is not sufficient for retail diversity where network integration is limited.

5.3. Implications for planning

Planning interventions in peripheral retail areas may be more effective when matched to the morphological condition of each context and to its weakest retail outcome. Because the MAF identifies which dimension, and which attribute, corresponds with each retail metric, it can indicate where retail vitality is limited and which plots are most relevant for intervention.

In composition-led contexts such as Helsinki, retail is concentrated within large plots and complexes, corresponding with high retail density but low agglomeration and diversity. Although diversity is only weakly associated with either indicator in Helsinki, local integration carries the largest weight among its variables (Table S14); interventions may focus on strengthening the local integration of high-capacity plots rather than increasing their capacity further. Plots of high compositional but low configurational value (Q4), which in Figure 8 show low retail diversity, are the most relevant targets: improving their permeability, introducing active frontages, and subdividing large complexes into independently accessible units, which prior research associates with a greater variety of retail occupiers and higher pedestrian activity (Marcus, 2010; Sevtsuk, 2020; Mohamed & Allani, 2025), may support a wider range of retail functions. Where blocks lack a clear distinction between public and private space, the plot no longer mediates between retail units, streets, and the wider urban system (Panerai et al., 2004). As retail in Helsinki is already concentrated within planned neighborhood centers, the challenge lies less in establishing local centers than in connecting them to their surroundings.

In configuration-led contexts such as Ankara, retail is organized along integrated corridors, corresponding with high agglomeration and diversity but low density. Retail density corresponds primarily with global integration, reflecting concentration along arterial roads, whereas diversity corresponds more strongly with node connectivity and local integration, and agglomeration with node connectivity (Table S14). Globally integrated corridors thus accommodate the concentration of retail activity, while its variety depends more on the local accessibility that characterizes neighborhood centers. Because retail in Ankara

is located predominantly along main roads, interventions may focus on maintaining and strengthening retail in locally accessible neighborhood centers rather than reinforcing further concentration along arterial corridors. Plots of high configurational value, in the upper range of Figures 6 and 8, remain relevant targets, where infill and intensified ground-floor uses on locally well-connected streets may support both density and diversity.

In intermediate contexts such as Vilnius, incremental and network-sensitive interventions may be more appropriate than large-scale restructuring. Plots low on both dimensions (Q3) indicate where combined improvements in capacity and connectivity could be considered. As plot frequency is negatively associated with retail diversity in Vilnius, further subdivision without improved network integration is unlikely to support retail variety.

These implications should be read in light of factors beyond morphology. Land price and income distribution may account for part of the observed associations, since retail concentrates where land values and purchasing power are high; yet land value is itself partly a function of network position and plot capacity, so morphology may operate partly through the market conditions it structures. Mobility is captured only indirectly: in Ankara, global integration largely coincides with arterial roads and may partly reflect car-based accessibility, while in Helsinki, proximity to rail and metro stations, which was not modelled, may contribute to retail concentration in compact nodes. Institutional factors, including zoning, regulatory regimes, and mall ownership, likely underlie much of the contrast between cities. Because the analysis was conducted within each city, where regulatory regimes are largely constant, the reported associations cannot be attributed to regulatory differences between cities, although local zoning and the location of individual malls may coincide with morphological differences. Mall ownership is particularly relevant in Helsinki, where establishments within large complexes, treated as separate units, may display a density and diversity reflecting management decisions rather than plot morphology. Plot-level data on land value, income, transit access, and zoning would allow these factors to be disentangled in future research.

Because these implications rest on cross-sectional associations, they indicate where interventions are likely to be relevant rather than predicting their effects. The MAF can nonetheless serve as a diagnostic tool, allowing planners to identify which morphological dimension carries retail vitality in a given context and which plots fall short of it.

6. Conclusions

This research examined how compositional and configurational plot attributes are associated with retail density, agglomeration, and diversity in the peripheral areas of Ankara, Helsinki, and Vilnius, and explored whether they correspond with retail cluster form. Applying the Morphological Assessment Framework to 5064 plots within 19 retail clusters, the findings show that retail density is associated primarily with compositional capacity, while retail agglomeration and, most consistently, retail diversity are associated with configurational character. These associations are configuration-led in Ankara, composition-led in Helsinki, and intermediate in Vilnius, while within each city the two dimensions are complementary rather than opposed. Cluster form differs between the cities, being elongated in Ankara and compact in Helsinki and Vilnius, but is not associated with plot-level morphological character at the cluster level.

The research makes three theoretical contributions. First, it contributes to a relational understanding of retail centrality by showing that retail outcomes are associated with both compositional and configurational plot attributes, whose relative weight depends on context. Whereas prior studies have examined configurational (Porta et al., 2012; Scoppa & Peponis, 2015) and compositional (Bobkova et al., 2019, 2021) aspects largely separately, this research examines both within a single plot-level framework. Second, it provides plot-scale evidence on the conditions of urban vitality identified by Jacobs (1961), previously operationalized mainly at the neighborhood scale (Sung et al., 2015; Gómez-Varo et al., 2022): in the three peripheral contexts examined, the intensity of retail activity corresponds with plot capacity, and its variety with network accessibility. Third, it offers plot-scale evidence for spatial capital theory (Marcus, 2026), suggesting that the variables of spatial form operate as complementary dimensions whose relative weight varies between contexts.

The MAF constitutes the methodological contribution. Plot-based urbanism describes the compositional structure of plot systems, space syntax measures the configurational position of streets, the node-place model evaluates the balance between accessibility and activity around station areas, and retail geography examines retail location in relation to street-based or economic factors. The MAF combines these perspectives at the plot scale by weighting compositional and configurational attributes according to their spatially varying associations with each retail metric, estimated through multiscale geographically weighted regression. This enables researchers to identify which dimension, and which attribute, carries each component of retail vitality in a given context, for example distinguishing plot-based from network-based agglomeration, or locally from globally accessible retail concentrations, and to locate plots that fall short of these conditions. Its transferability therefore lies in the framework rather than in its results: because weights are recalibrated for each context, it identifies context-specific relationships rather than assuming uniform effects, and the differences between the cities are one of its main outputs. Its performance in smaller cities, central areas, or contexts with different data availability nonetheless remains to be tested.

Several limitations should be noted. The three cases are capital cities, whose retail markets and development pressures may differ from those of other urban areas. Retail trade and food services were analyzed as a combined category, which may obscure sector-specific patterns. The

cross-sectional design identifies associations rather than causal relationships, and because the composite indicators are weighted by the MGWR coefficients of each retail metric, they describe how these associations are distributed between the two dimensions rather than testing them independently. The cluster-level analysis, based on 19 clusters, remains exploratory. The distance thresholds used to delineate catchments and calculate the morphological and retail metrics were adopted from the literature and were not subjected to sensitivity testing. The analysis also considers a limited set of morphological attributes, excluding street width and multimodal accessibility, and does not include market, mobility, or institutional variables at the plot scale, nor the experiential qualities, such as comfort, climate, and design quality, that user-based studies identify as conditions of retail vitality (Mohamed & Allani, 2024, 2025). Finally, retail data from Google Maps and OpenStreetMap may vary in coverage between countries, which may affect cross-city comparisons. Future research could apply the MAF to comparisons within a single institutional setting, analyze retail sectors separately, adopt longitudinal designs linking morphological and retail change, incorporate plot-level data on land value, income, transit access, and zoning, and examine a larger number of clusters to test the relationship between plot morphology and cluster form more fully.

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