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# Urban Spatial Configuration and Non-Communicable Disease Prevalence in Doha, Qatar: An Ecological Spatial Analysis

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## Abstract

# (Background)

The rapid urban transformation of Doha has intensified interest in how the spatial configuration of the built environment shapes patterns of chronic disease. While international evidence links walkability, network structure, and environmental exposure to non-communicable diseases (NCDs), such relationships remain under-examined in hot-arid Gulf cities, highlighting an opportunity for public health action.

# (Objective)

This study investigates what spatial conditions characterise Doha's planning zones and how urban configuration relates to the distribution of selected NCDs. It maps municipal-scale variation in space syntax metrics, visualises patterns of NCD prevalence, and interprets linkages between health and morphology through behavioural and environmental pathways.

# (Methods)

A cross-sectional ecological spatial study conducted across 56 zones using space syntax indicators and GIS-based mapping of clinically verified NCD prevalence. Spatial clustering was assessed through Moran's I and LISA maps.

# (Results)

Distinct morphological gradients were observed, from highly integrated inner-city street networks to coarse-grained peripheral superblocks. Obesity (11.1–50.0%) and hypertension (5.6–28.1%) showed the clearest spatial structuring, occurring more frequently in zones characterised by lower network integration, reduced permeability, and larger block sixes. COPD (1.7–12.5%) exhibited a distinct clustering pattern, occurring more often in large-block, corridor-oriented districts consistent with traffic-related exposure contexts. Diabetes (4.0–26.5%) showed weak spatial structuring and no consistent alignment with configurational measures at the planning-zone scale.

# (Conclusions)

Urban configuration in Doha is associated with outcome-specific chronic disease patterns, with cardiometabolic conditions and chronic pulmonary health outcomes showing clear sensitivity to urban design and street-network configuration, while diabetes does not exhibit a consistent spatial association at the neighbourhood scale. Integrating key configurational indicators into municipal planning can

support the identification of spatial health vulnerabilities and the prioritisation of health-supportive interventions in hot-arid cities. scale

# 1. Introduction

Non-communicable diseases (NCDs) represent the leading cause of mortality worldwide, with their prevalence driven primarily by modifiable behavioural and environmental risk factors (World Health Organization, 2014). Within the Social Determinants of Health (SDH) framework, these health outcomes are understood not merely as the result of individual lifestyle choices, but as the product of a wider set of structural conditions embedded in the built environment. These include housing quality, transportation systems, environmental exposures, access to essential services, and neighbourhood design, rather than from individual behaviour alone (Solar & Irwin, 2006). Collectively, these conditions' structure everyday exposure patterns and significantly influence opportunities for physical activity, social interaction, and access to health-supportive resources, thereby shaping population health and overall well-being.

Within this broader built-environment context, urban form–particularly street-network configuration–plays a distinct and measurable role in shaping everyday mobility patterns, by influencing how people move through space, access destinations, and interact with their surroundings. Characteristics such as street connectivity, network integration, and block structure influence the feasibility of routine walking, route choice, and exposure to traffic or environmental stressors. In supportive urban configurations, permeable and fine-grained networks can facilitate walking and access to local amenities, whereas in car-oriented environments characterised by coarse grain and disconnected layouts, daily mobility tend to be more constrained and reliant on private cars (Giles-Corti et al., 2016; Stevenson et al., 2016a).

This challenge is particularly acute in the Gulf Cooperation Council (GCC) region, where rapid socioeconomic development and oil-driven modernisation has driven profound lifestyle and mobility shifts (Salama & Wiedmann, 2013). Doha presents a paradigmatic case of this phenomenon. Over the past several decades, the city has undergone rapid urbanization, transforming from a compact town into a large-scale metropolis. This expansion has produced a complex urban mosaic, ranging from the dense, organically formed, rehabilitated fabric of the historic core to coarse-grained suburban superblocks dominated by looped street systems designed primarily for vehicular movement. Such spatial transformation has entrenched automobile dependency, which, when exacerbated by extreme heat and climatic constraints, constitutes a critical structural driver of the region's public health challenges.

In Qatar, non-communicable diseases (NCDs) account for an estimated 69% of all deaths, primarily due to cardiovascular disease (24%), cancer (18%), and diabetes (7%) (Ministry of Public Health Qatar., 2018; World Health Organization, 2015). National surveys report that 70.1% of adults are overweight and 43.9% are physically inactive (Ministry of Public Health Qatar., 2018). Recent evidence indicates that Qatar ranks among countries with the highest global prevalence of diabetes and obesity, posing a growing threat to both public health systems and long-term economic sustainability (Al-Abdulla et al., 2024).

Without systemic preventive interventions, obesity prevalence is projected to rise significantly by 2030, with disproportionate impacts on working-age adults and women (World Obesity Atlas, 2022).

Although international research has consistently demonstrated associations between urban environments and chronic disease risk, empirical studies that explicitly link street-network configuration to population health outcomes in Gulf cities remain scarce. In Doha, rapid and uneven urban expansion has produced pronounced spatial heterogeneity in street connectivity, network integration, and block grain; however, the extent to which these configurational differences align with observed NCD patterns has not been systematically examined. This absence of spatially explicit morphology-health evidence represents a critical gap for advancing health-responsive and climate-sensitive urban design in hot-arid contexts.

To address this gap, this study investigates the relationship between neighbourhood spatial configuration and the prevalence of major NCD in Doha by integrating space syntax-based configurational metrics with aggregated epidemiological data.

The objectives of the study are:

- To compute and spatially map key space syntax measures (including integration, choice, and connectivity) across Doha's street network, with an advancement toward zone-level aggregation to support urban health analysis.
- To examine whether patterns of configurational exposure align with observed NCD prevalence, using spatial clustering techniques and descriptive comparison analysis, given the ecological nature of the dataset.
- To interpret the observed associations through plausible spatial–health pathways and propose morphology-informed urban planning and policy recommendations relevant to hot-arid, car-dependent cities.

## 2. Literature Review

# 2.1 Urban Health and the Built Environment: Global and GCC Perspectives

Urban health has evolved from early concerns with sanitation, overcrowding, and infectious diseases in industrial cities to a broader focus on how everyday environments shape the risk of chronic disease (Vaughan, 2018). The Social Determinants of Health (SDH) framework is central to this understanding, conceptualising health as emerging from social, economic, and environmental conditions rather than individual choices alone (Solar & Irwin, 2006). This emphasis underscores the importance of social factors in urban health research.

Positioning the built environment within the SDH framework reframes urban form as a structural exposure domain: street networks, land-use patterns, and accessibility to destinations co-produce opportunities for physical activity, social interaction, and access to services. This underscores the vital role urban morphology plays in shaping health, encouraging urban planners and academics to see their work as directly impactful.

A substantial body of public health scholarship demonstrates that the physical structure of cities is a foundational component affecting public health outcomes. Neighbourhood features such as street connectivity, land-use diversity, access to destinations, and the availability of walkable environments influence daily mobility patterns, exposure to environmental stressors, social interaction, and opportunities for physical activity, which in turn are linked to the prevalence of non-communicable diseases (NCDs) such as obesity, hypertension, cardiovascular disease, and Type 2 diabetes. Global evidence consistently shows that highly walkable, mixed-use, well-connected neighbourhoods are associated with lower rates of these conditions, whereas fragmented, car-dependent environments systematically suppress physical activity and increase the risk of chronic disease (Fazeli Dehkordi et al., 2022; Li et al., 2024; Sallis et al., 2016; Stevenson et al., 2016b). This reinforces the built environment as an upstream public-health determinant that simultaneously shapes behavioural, psychosocial, and environmental exposures. From this perspective, neighbourhood configuration functions as a modifiable upstream determinant within the health-production system. The concept of “obesogenic environments” further highlights how built-form characteristics, food accessibility, and mobility systems interact to shape dietary behaviour and physical inactivity patterns at the neighbourhood scale (Lake & Townshend, 2006).

Regional public-health studies consistently report high levels of sedentary behaviour, physical inactivity, and obesity, frequently attributing these patterns to environmental barriers and car-dependent urban form (Chaabna et al., 2022). However, much of this research focuses on individual behaviours or clinical risk factors within specific population groups rather than examining neighbourhood spatial structure as an upstream determinant shaping daily mobility and exposure. Fine-scale spatial analyses in other contexts have shown that obesity rates cluster geographically and often align with neighbourhood socioeconomic and environmental conditions (Drewnowski et al., 2007). Similarly, studies on healthcare access and utilisation provide valuable evidence but do not typically assess how configurational urban morphology may contribute to chronic disease risk (Al-Kuwari et al., 2021; Syed et al., 2024).

Overall, relatively few GCC studies directly evaluate associations between objective configurational measures (e.g., integration, connectivity, choice, block structure) and population health outcomes (Chaabna et al., 2022; Major & Dalton, 2018; Nes & Yamu, 2021). Many investigations rely instead on indirect proxies such as perceived walkability, distance measures, or coarse density indicators (Al-Kuwari et al., 2021). As highlighted in systematic reviews, research in hot-arid Gulf cities rarely incorporates metrics such as block size, integration, or connectivity despite their relevance for movement potential and exposure pathways (Fazeli Dehkordi et al., 2022; Koohsari et al., 2017). This gap motivates

ecological, city-scale studies that integrate configurational analysis with clinically verified NCD data to clarify how the spatial structure of GCC cities aligns with chronic disease patterns.

Importantly, the built environment may also influence health through psychosocial pathways in addition to physical activity. Evidence from other contexts suggests that permeable, connected layouts can support casual encounters, informal surveillance, and perceived safety, which are linked to social cohesion and mental well-being. Abu-Ghazzeh (1999) for instance, examined how housing layout relates to social contact patterns through field-based assessment of interaction spaces, while (Leyden, 2003) used cross-sectional resident surveys to link walkable neighbourhood characteristics with social capital. In their paper, Burton et al. (2011) developed objective built-environment indicators to examine associations with older adults' wellbeing. Although these studies do not consistently operationalise spatial structure through space syntax metrics, they collectively support the broader proposition that spatial configuration can shape social processes relevant to health.

Taken together, this literature suggests that urban health outcomes are shaped by the spatial configuration of the built environment through interconnected physical, environmental, and psychosocial pathways, while highlighting a persistent lack of configurational, spatially explicit evidence in hot-arid GCC cities.

## 2.2 Methods for Assessing the Built Environment in Health Research

Traditional built-environment indicators such as residential density, land-use mix, and proximity to amenities describe urban form in static terms but fail to capture its relational qualities. Batty refers to this approach as "the geography of locations, not relations... (which) largely avoids even the most rudimentary distortions of… space as reflected, for example, in the notion of the network" (Batty quoted in (Hillier, 2005; 7). For this, Hillier (2005) cites (Batty, 2003, 2004) based on working papers for the Centre for Spatial Analysis (CASA). They do not explain how streets connect, how movement flows, or how accessible neighbourhoods truly are (B. Hillier & Hanson, 1984; W. Hillier et al., 2012). As a result, they overlook the movement potential embedded within the street network, which is critical for understanding how urban form shapes health behaviours.

To address the shortcomings of conventional indicators, urban health research increasingly employs configurational approaches, which interpret cities as relational movement networks rather than collections of parcels (Mohamed & van der Laag Yamu, 2024). Space syntax provides key quantitative metrics based on spatial configuration, such as integration, connectivity, choice, and mean depth, that are essential for understanding how urban spatial structure shapes accessibility, movement patterns, and social interactions across scales (B. Hillier & Hanson, 1984; B. Hillier & Vaughan, 2007; W. Hillier et al., 2012). These measures are used to evaluate urban health outcomes by capturing how spatial configuration influences pedestrian accessibility and social interactions. Integration captures how centrally a street segment sits within the overall network; connectivity reflects the number of immediate route options; and choice approximates the potential for through movement along key corridors

(Vaughan & McEachan, 2024). Together, these indicators provide a nuanced description of movement opportunities that is not obtainable from density or land-use measures alone.

Urban morphology shapes health through multiple interconnected mechanisms. Fine-grained, permeable street networks and access to green spaces can make urban environments feel more welcoming and supportive, encouraging active lifestyles and fostering a sense of community (Nieuwenhuijsen, 2020; Stevenson et al., 2016b). Well-connected environments also enhance opportunities for social interaction, informal surveillance, and perceived safety, e.g., factors that support mental well-being and resilience (Abu-Ghazzeh, 1999; Burton et al., 2011; Leyden, 2003). Recent work in spatial epidemiology has begun to integrate configurational metrics with health outcomes, demonstrating associations between street-network structure, physical activity, and metabolic risk across diverse urban contexts (Andrees et al., 2024; Vaughan & McEachan, 2024). However, their application in hot-arid, car-dependent areas remains limited, prompting further investigation into context-specific urban design strategies.

Collectively, this methodological literature suggests that configurational approaches such as space syntax provide a more robust means of capturing movement potential and spatial accessibility than conventional density- or proximity-based indicators in urban health research.

## 2.3 Research Gaps and Rationale for the Study

Despite global advances in epidemiology and spatial analysis, two critical gaps remain particularly salient for Doha and comparable Gulf cities, particularly in urban health research that employs spatially grounded, location-specific data.

- **Geographical gap**: Existing GCC studies rarely incorporate detailed morphological information alongside population health outcomes, highlighting the urgent need for more comprehensive, location-specific studies in Doha to inform research and policy development.
- **Methodological gap**: Previous work tends to rely on proxy measures of urban form (e.g., density, land-use mix, or self-reported neighbourhood characteristics), rather than using configurational measures that directly capture spatial accessibility and movement potential.

Addressing these gaps contributes first and foremost to the scholarly literature by advancing empirical understanding of how urban spatial configuration operates as an upstream determinant of health within hot-arid, car-dependent contexts, an area that remains underrepresented in urban health and planning research. By combining configurational metrics with clinically verified NCD data across all 56 administrative zones of Doha, this study extends existing methodological approaches and offers a city-scale framework for spatial health analysis that is transferable to other Gulf cities. At the national and planning-policy scale, these insights directly align with Qatar's National Master Plan and Qatar National Vision 2030 (QNV2030), both of which emphasize health-responsive, walkable, and sustainable urban development. In this regard, the study provides an evidence-based foundation to support policy formulation, spatial prioritisation, and health-integrated planning interventions within Qatar and the wider GCC region.

Overall, these gaps underscore the need for city-scale, spatially explicit analyses that integrate configurational urban metrics with clinically verified health data to inform health-responsive planning in hot-arid, car-dependent contexts such as Doha.

# 3. Methodology

This study adopts a cross-sectional ecological approach to examine how planning zone-scale urban morphology is associated with non-communicable disease (NCD) prevalence across the Doha Municipality. Guided by the Social Determinants of Health (SDH) framework, the built-environment morphology is specified as the exposure domain and NCD prevalence as the response domain, with socioeconomic deprivation and population density included as SDH-related covariates. General demographic trends in NCDs were used in the total population as a control factor. This focus aims to contribute valuable insights to the fields of public health and urban planning.

# 3.1 Study Area

Doha is the capital and the largest metropolitan area in Qatar by population. It is the smallest municipality by area and represents a distinctive example of a hot-arid, and automobile-dependent GCC city. Over the past three decades, Doha has undergone extensive urban transformation, shifting from a compact historic core to dispersed, low-density, auto-oriented expansion. This evolution is highly relevant to understanding non-communicable disease (NCD) outcomes under extreme climatic conditions, as the resulting spatial heterogeneity provides a valuable context for examination.

There are fifty-six (56) planning zones in the Doha Municipality. Planning zones are the smallest units for which clinically verified NCD data were available at the operational scale of Qatar's National Master Plan. However, analysis is conducted across only fifty (50) zones. Six (6) zones with a residential population of less than 100 people are eliminated from the dataset. The six eliminated zones include Zone 2 (Amiri Diwan), Zone 7 (Al Souq), Zone 12 (Al Bidda Park), Zone 19 (Old Port), Zone 60 (Al Corniche commercial tower area), and Zone 62 (Sports Complex). Space syntax measures were based on a 2024 model of the urban spatial network, aggregated at the individual zone level, and integrated with demographic and epidemiological data to evaluate zone-level spatial–health associations. This comprehensive data integration aims to enhance the credibility of the findings and support evidence-based urban health strategies.

The chosen scale captures zone-level variation in urban form, sufficiently fine to reveal configurational and infrastructural contrasts, yet broad enough to maintain statistical reliability for aggregated health data. This scale also corresponds to the level at which residents interact with their everyday environment, making it appropriate for examining links between urban morphology, exposure patterns, and health outcomes in a hot-arid, automobile-oriented context such as Doha. Doha Municipality, within the national context, illustrates the spatial extent of the 56 zones used as analytical units (Fig. 1).

# 3.2 Data Sources and Preparation

All datasets were carefully prepared for Doha Municipality and aggregated to Planning and Statistics Authority (PSA) zones (N = 50). Spatial processing was performed using WGS 84/UTM Zone 39N. The zone layer was topology-checked (no gaps/overlaps), clipped to the municipal boundary/coastline, and harmonized on a unique Zone_ID field for table joins.

All variables were compiled into a unified Excel database, with the zone code serving as the shared key. Each record represented one of Doha's planning zones and contained corresponding health, urban form, land use, and socioeconomic indicators, as well as accumulated space syntax measures for each zone. The dataset was cleaned, standardised, and verified for completeness, enabling effective use in GIS for mapping and analysis. This process ensured alignment across datasets and allowed direct comparison of spatial configuration and health outcomes across zones.

# 3.2.1 Health Data

Clinical datasets were obtained from the electronic health record (EHR) system of the Primary Health Care Corporation (PHCC), Qatar's largest publicly funded primary care provider. Anonymised zone-level data for residents aged ≥ 18 years were extracted for 2024, comprising 25,023 eligible individuals. Diagnoses of Diabetes Mellitus, Hypertension, Cardiovascular Disease, and Chronic Obstructive Airway Diseases (COPD) were verified using SNOMED clinical codes to ensure data accuracy and reliability. Where available, height and weight were extracted to calculate BMI, and individuals were classified as overweight/obese (BMI ≥ 25 kg/m²) or obese (≥ 30 kg/m²). Prevalence rates were computed using IBM SPSS (Version 28) for statistical analysis. All data were anonymised, presented minimal confidentiality risk to participants, and complied with ethical standards. Approval was granted by PHCC's Institutional Review Board (IRB Reference: BUHOOTH-D-25-00056).

Two contextual variables were included as control variables:

- Population Density (persons per km²): proxy for urban intensity and service access.
- Socioeconomic Deprivation Index (SDI): a composite indicator of socioeconomic disadvantage.

Both were mean-centred and standardised to minimise collinearity and ensure comparability with spatial measures.

# 3.2.2 Space Syntax Measures

Space syntax is the primary morphological framework for the study because it captures the relational structure of streets, rather than static features. This allows us to quantify how the spatial configuration of the environment influences movement and how specific zones may structurally deter healthy behaviour. The DepthMapX software was used to characterise the configurational properties of Doha's urban spatial network using several standard space syntax measures. All measures were aggregated to the zone level with and without perimeter streets defining the edges of each zone.

To focus on internal neighbourhood movement patterns, major boundary and arterial streets were excluded from the primary aggregation process. This step minimises the influence of city-scale through-movement and ensures that configurational values reflect pedestrian-relevant street structure within zones rather than traffic-dominated corridors.

Each measure is as follows:

- Connectivity (Average): Connectivity represents the number of immediately adjacent routes that intersect with a given route. It is a pure topological count and therefore unitless. Higher values indicate more permeable, fine-grained networks with numerous local route options.
- Integration [HH] (Average): Integration (Hillier–Hanson normalization) quantifies the ease with which a route can be reached from all other routes within the spatial network. It is a relative accessibility measure derived from graph-theoretic depth and is dimensionless. Higher values signify more accessible and integrated routes, whereas lower values indicate less accessible and more segregated ones.
- Integration [HH] R3 (Average): This is the same integration measure calculated within a restricted radius of three topological steps, capturing localised accessibility. Like global integration, it is unitless and reflects localised movement potential and routes centrality within a local area.
- Line Length (Average): Line Length is the average metric length of routes within each zone. DepthMapX exports this data as the number of pixels, which researchers then relativise to actual length using Google Earth Pro measurement tools.
- Choice (Global Choice): Choice denotes the probability that a route will be selected as part of the shortest path for all possible origin–destination pairs in the network. It functions as a proxy for movement flow potential, highlighting streets that serve as key through-routes. Higher choice values typically indicate routes that attract greater movement or commercial activities due to their strategic position within the foreground network of the urban spatial system. In contrast, lower choice values indicate routes that form part of its background network (Hillier & Vaughan, 2007).
- Mean Depth (Average): Mean depth captures the average number of topological steps required to reach all other routes from a given route. Because depth denotes the number of topological steps, it is dimensionless. Larger values indicate deeply nested routes within the urban spatial network. Lower values represent spatially shallow ones.

To characterize the fineness or coarseness of Doha's urban fabric, the Mean Block Area (MBA) was estimated using Major & Dalton (2018) methodology. This method derives block size indirectly from space syntax network measures rather than from polygonal block boundaries. The approach uses the length of each street segment and its connectivity (the number of direct intersections with other segments) to infer the average block size within the network. Longer, less-connected routes indicate larger blocks, while shorter, more highly connected ones reflect finer-grained, walkable urban fabrics. For each zone, the average route length divided by the average connectivity was calculated from these

relationships and then squared (assuming the blocks were square-shaped) to represent a typical block size for the zone.

## 3.3 Data Analysis

The research strategy integrated two complementary analytical pathways within a unified spatial analysis framework, aligned with the study objectives (Fig. 2). First, spatial analysis was conducted to assess whether non-communicable diseases (NCDs) exhibit statistically structured patterns across Doha using space syntax measures. Second, a comparative interpretation was undertaken to examine whether variations in zone-level configurations align with the observed spatial distribution of NCD prevalence.

These parallel streams — built-environment morphology and health outcomes — were analysed using GIS-based spatial techniques and interpreted jointly within the Social Determinants of Health (SDH) framework, enabling an integrated assessment of how urban morphology and population health co-vary spatially at the municipal scale.

A street-network model of Doha Municipality was constructed in DepthmapX to compute configurational measures used in the analysis (Fig. 3). The model was derived from the municipal street-centreline layer and cleaned to ensure topological continuity by removing duplicate features, correcting overshoots/undershoots, and excluding non-navigable artefacts. The network was then converted to a segment-based representation to support movement-sensitive analysis. Following space syntax conventions, integration was used to represent relative accessibility within the network, choice to represent potential through-movement along shortest paths, and connectivity to represent local route options at the segment level.

The modelling workflow followed established space syntax procedures commonly used in urban morphology research, drawing particularly on the methodological approach described by (Major & Dalton, 2018). The base DepthmapX model was initially prepared by Dr. Mark David Major and Heba O. Tannous, after which the authors performed additional cleaning, recalculation, and export steps for the 2024 network (Major et al., 2021,Major et al., 2026). Route-based analysis produced the core configurational indicators used in this study—global integration (HH), local integration (HH R3), connectivity, global choice, mean depth, and line length—as zone-relevant measures of accessibility, permeability, and network structure.

Before analysing associations, spatial dependence was evaluated to confirm the presence of non-random spatial patterns in health outcomes, ensuring the relevance of subsequent spatial analyses. Global Moran's I was used to measure the overall spatial autocorrelation of each NCD variable (diabetes, hypertension, cardiovascular disease, and COPD). Local Moran's I (LISA) was used to detect specific spatial clusters and outliers, revealing zones with similar or contrasting values around high- or low-prevalence areas. The analysis used a first-order queen contiguity weight matrix, 999 permutations, and a Benjamini–Hochberg FDR correction at $p < 0.05$, with mapping conducted in ArcGIS Pro 3.x.

# 4. Results

# 4.1 Descriptive Characteristics of Built Environment and NCDs

NCD prevalence varied across Doha's analysed zones (Table 1). Diabetes Mellitus ranged from 4.00% to 26.50%, hypertension from 5.55% to 28.11%, cardiovascular disease from 1.30% to 11.11%, and COPD from 1.73% to 12.52%. Obesity ranged from 11.11% to 50.00%, while combined overweight/obesity ranged from 50.00% to 76.07%. Full descriptive statistics for all NCD outcomes are reported in Table 1.

Built-environment morphology also demonstrated wide inter-zonal variation (Table 1). Connectivity ranged from 2.80 to 7.32, global integration (HH) from 0.78 to 1.28, and local integration (HH R3) from 1.42 to 10.47. Line length ranged from 98.50 m to 798.55 m, mean depth from 10.53 to 17.10, and mean block size from 260.9 m² to 31,860.7 m². Full descriptive statistics for all morphology indicators are reported in Table 1.

Table 1
Descriptive statistics for NCD prevalence and built-environment morphology across 50 zones in Doha

(Source: Authors).

| **NCDs Variables** | **Mean** | **Min** | **Max** | |
|---|---|---|---|---|
| Diabetes Mellitus | 15.24 | 4.00 | 26.50 | |
| Hypertension | 18.09 | 5.55 | 28.11 | |
| Cardiovascular Disease | 5.51 | 1.30 | 11.11 | |
| COPD | 6.73 | 1.73 | 12.52 | |
| Obesity | 32.30 | 11.11 | 50.00 | |
| Overweight and Obesity | 70.93 | 50.00 | 76.07 | |
| Morphology Variables (Avg.) | **Mean** | **Min** | **Max** | **SD** |
| Connectivity | 4.20 | 2.80 | 7.32 | 1.06 |
| Integration (HH) | 1.08 | 0.78 | 1.28 | 0.13 |
| Integration (HH) R3 | 1.95 | 1.42 | 10.47 | 1.17 |
| Real Line Length (m) | 239.57 | 98.50 | 798.55 | 123.93 |
| Mean Depth | 12.46 | 10.53 | 17.10 | 1.62 |
| Choice (Norm) | 0.0021 | 0.0002 | 0.0057 | 0.0016 |
| Block Size (m²) | 5,642.85 | 260.9 | 31,860.7 | 7,176.96 |

Overall, these descriptive patterns highlight substantial inter-zonal variability in both NCD prevalence and built-environment morphology across Doha, establishing the basis for subsequent spatial analysis.

## 4.2 Choropleth Maps of NCDs Distribution

(Fig. 4) and (Table 2) summarises the spatial distribution of NCD prevalence across Doha's zones. Diabetes Mellitus has a higher prevalence in several central zones within the D-Ring Road, with additional higher-prevalence zones along the northwestern corridor associated with the Doha Expressway and C-Ring Road. Hypertension and cardiovascular disease show a similar but less pronounced pattern, with partial overlap between higher-prevalence zones for these conditions and those observed for diabetes. COPD exhibits a more localised pattern, with elevated prevalence concentrated in a smaller set of zones.

Table 2

Zone-by-zone summary of chronic health conditions and weight status across the 50 analysed zones in Doha Municipality, including prevalence (%) of Diabetes Mellitus, Hypertension, Cardiovascular Disease, Asthma/COPD, Overweight, and Obesity

(Source: Authors; data aggregated to zone level from the Primary Health Care Corporation).

| Zone | Diabetes Mellitus % | Hypertension % | Cardiovascular Disease % | Asthma and (COPD) % | Overweight % | Obese % |
|---|---|---|---|---|---|---|
| 1 | 4.00 | 12.00 | 4.00 | 0.00 | 71.43 | 28.57 |
| 3 | 5.00 | 5.83 | 1.67 | 4.58 | 63.51 | 25.68 |
| 4 | 19.77 | 18.64 | 6.21 | 5.08 | 67.30 | 22.01 |
| 5 | 26.51 | 28.11 | 8.43 | 6.83 | 75.00 | 22.58 |
| 6 | 24.94 | 28.05 | 8.31 | 3.90 | 73.79 | 35.86 |
| 13 | 11.67 | 14.27 | 3.93 | 5.10 | 74.33 | 32.55 |
| 14 | 15.16 | 16.78 | 4.68 | 6.24 | 74.46 | 34.33 |
| 15 | 15.92 | 17.16 | 5.71 | 5.40 | 73.94 | 32.53 |
| 16 | 18.97 | 19.08 | 6.63 | 5.37 | 73.00 | 33.77 |
| 17 | 17.77 | 20.45 | 5.90 | 5.15 | 73.03 | 32.73 |
| 18 | 12.01 | 16.23 | 4.64 | 4.77 | 73.68 | 39.32 |
| 20 | 12.44 | 15.61 | 5.12 | 7.07 | 68.13 | 31.47 |
| 21 | 9.42 | 19.07 | 3.77 | 12.53 | 55.74 | 22.95 |
| 22 | 14.94 | 18.79 | 5.26 | 7.40 | 74.58 | 34.96 |
| 23 | 14.06 | 17.76 | 5.18 | 6.29 | 74.03 | 34.43 |
| 24 | 16.87 | 20.36 | 5.46 | 7.49 | 75.48 | 36.09 |
| 25 | 15.93 | 20.10 | 4.95 | 6.05 | 73.54 | 34.89 |
| 26 | 17.65 | 20.41 | 5.73 | 6.03 | 74.19 | 35.17 |
| 27 | 16.75 | 18.87 | 4.98 | 5.45 | 72.71 | 33.55 |
| 28 | 20.30 | 23.55 | 7.71 | 8.53 | 71.61 | 35.28 |
| 29 | 5.56 | 5.56 | 2.78 | 0.00 | 71.43 | 0.00 |
| 30 | 16.01 | 16.94 | 5.11 | 7.70 | 67.75 | 32.05 |
| 31 | 14.62 | 16.91 | 4.67 | 5.97 | 69.93 | 32.54 |
| 32 | 17.14 | 19.37 | 4.98 | 8.01 | 71.03 | 34.03 |

| Zone | Diabetes Mellitus % | Hypertension % | Cardiovascular Disease % | Asthma and (COPD) % | Overweight % | Obese % |
|---|---|---|---|---|---|---|
| 33 | 15.91 | 18.85 | 5.56 | 7.52 | 72.90 | 34.38 |
| 34 | 18.65 | 20.43 | 5.43 | 7.90 | 74.92 | 37.64 |
| 35 | 17.43 | 20.41 | 5.58 | 7.83 | 76.07 | 37.52 |
| 36 | 14.02 | 18.24 | 4.58 | 6.90 | 71.18 | 33.94 |
| 37 | 17.72 | 20.75 | 5.59 | 7.77 | 73.08 | 35.07 |
| 38 | 13.85 | 17.81 | 5.26 | 6.44 | 72.64 | 33.85 |
| 39 | 15.13 | 19.53 | 5.51 | 7.03 | 72.87 | 33.90 |
| 40 | 17.10 | 20.26 | 5.81 | 7.02 | 72.06 | 32.68 |
| 41 | 19.15 | 22.52 | 6.41 | 7.32 | 70.12 | 34.26 |
| 42 | 18.72 | 21.95 | 6.81 | 7.07 | 69.66 | 31.30 |
| 43 | 18.25 | 19.90 | 6.05 | 8.27 | 71.88 | 33.73 |
| 44 | 16.82 | 19.52 | 5.26 | 7.01 | 70.49 | 33.23 |
| 45 | 17.55 | 20.94 | 5.60 | 6.72 | 72.71 | 33.97 |
| 46 | 13.41 | 16.61 | 4.76 | 5.91 | 73.25 | 33.83 |
| 47 | 15.98 | 19.77 | 5.66 | 6.38 | 69.96 | 31.61 |
| 48 | 12.83 | 17.84 | 5.41 | 7.41 | 73.42 | 32.28 |
| 49 | 0.00 | 0.00 | 0.00 | 0.00 | 50.00 | 25.00 |
| 50 | 12.30 | 15.79 | 3.57 | 5.39 | 74.46 | 34.94 |
| 57 | 18.71 | 21.09 | 7.63 | 4.16 | 68.50 | 23.81 |
| 61 | 8.77 | 12.39 | 4.79 | 4.17 | 68.40 | 30.72 |
| 63 | 13.22 | 15.88 | 5.08 | 5.95 | 69.92 | 31.26 |
| 64 | 18.52 | 20.69 | 6.86 | 7.37 | 69.97 | 32.47 |
| 65 | 18.87 | 19.70 | 5.45 | 8.95 | 68.94 | 32.90 |
| 66 | 12.71 | 15.69 | 5.28 | 6.22 | 66.22 | 28.93 |
| 67 | 17.90 | 19.27 | 5.52 | 8.85 | 69.61 | 32.46 |
| 68 | 15.17 | 16.43 | 5.20 | 8.62 | 69.48 | 34.18 |

Weight-related outcomes are shown in Fig. 4c (obesity) and Fig. 4f (combined overweight/obesity). The combined overweight/obesity measure shows a broad area of elevated prevalence across central and southern zones, including areas north and south of Salwa Road within the B- and C-Ring Road. Several of these areas coincide spatially with zones of higher prevalence of diabetes and hypertension. In contrast, obesity alone appears more diffuse, with comparatively lower prevalence in zone 49 and zone 29. Together, these maps indicate substantial inter-zonal variation and suggest that spatial patterns differ by outcome.

# 4.3 Spatial Autocorrelation of NCD Prevalence

## 4.3.1 Global Spatial Autocorrelation (Moran's I)

Global Moran's I indicated statistically structured spatial patterning for several NCD outcomes across Doha (Table 3). COPD exhibited the strongest positive spatial autocorrelation, whereas obesity and hypertension also showed significant positive clustering. Cardiovascular disease and diabetes showed weaker positive tendencies that did not reach conventional significance thresholds. These findings indicate that several NCD outcomes exhibit non-random spatial structuring at the municipal scale, warranting further localised cluster analysis.

Table 3
Global Moran's I for NCD prevalence across Doha's zones

(Source: Authors).

| NCD Type | Moran's I | Z-Score | p-Value | Spatial Pattern | Significance |
|---|---|---|---|---|---|
| COPD (Obstructive Airway Disease) | 0.248408 | 3.428319 | 0.000607 | Strong clustering | Highly significant ($p < 0.05$) |
| Obesity | 0.148342 | 2.522803 | 0.011642 | positive clustering | Significant ($p < 0.05$) |
| Hypertension | 0.138534 | 2.062372 | 0.039172 | positive Clustered | Significant ($p < 0.05$) |
| Cardiovascular Disease | 0.118972 | 1.789100 | 0.073599 | Weak clustering | Not significant |
| Diabetes Mellitus | 0.102753 | 1.553106 | 0.120398 | Weak clustering | Not significant |

## 4.3.2 Local Spatial Autocorrelation (LISA)

Local Moran's I (LISA) results are presented in Fig. 5. The maps identify local clusters and spatial outliers for COPD, hypertension, and obesity across the zones, highlighting areas where elevated prevalence is

surrounded by similarly high-prevalence neighbours (high–high clusters) and areas of consistently lower prevalence (low–low clusters). The identified local clusters and outliers reveal spatial heterogeneity in disease prevalence, highlighting specific zones where NCD patterns are locally concentrated or dispersed.

## 4.4 Spatial Configuration Patterns Across Doha

Spatial configuration mapping (Fig. 6) and (Table 4) show a clear centre–periphery structure. Higher global and local integration values are concentrated in the inner zones, while lower integration is more common in the peripheral zones. Connectivity exhibits a similar pattern, with higher values in central zones and lower values in peripheral districts. Mean depth increases toward outer zones, indicating deeper, more segregated network structures. Choice highlights zones that contain major through-movement corridors within the city-wide network. The block size (Fig. 6f) shows a pronounced contrast between compact block structures and large superblocks across Doha. Real line length (Fig. 7) shows similarly wide variation across zones, with shorter segments more common in some inner zones and longer arterial segments more common in several peripheral zones. All in all, these configurational patterns demonstrate a pronounced centre–periphery differentiation in Doha's street network, providing a spatial context for interpreting observed health patterns.

Table 4
Zone-by-zone summary of space syntax and grain indicators across the 50 analysed zones in Doha Municipality, including Choice Norm, Connectivity, Integration (HH), Local Integration (HH R3), mean real line length, mean depth, and mean block area

(Source: Authors; DepthMapX outputs aggregated to zone level).

| Zone | Choice [Norm] | Connectivity | Integration [HH] | Integration [HH] R3 | Real Line Length (m) | Mean Depth | Block size (m²) |
|---|---|---|---|---|---|---|---|
| 1 | 0.0005 | 6.6645 | 1.1362 | 2.4778 | 109.7054 | 11.7555 | 4352.01 |
| 3 | 0.0035 | 6.8378 | 1.2492 | 2.3000 | 120.4321 | 10.7791 | 4672.64 |
| 4 | 0.0003 | 5.1096 | 1.1623 | 2.3051 | 286.0824 | 11.3521 | 1983.1 |
| 5 | 0.0024 | 5.4000 | 1.1253 | 2.4788 | 234.9088 | 11.8942 | 4535.37 |
| 6 | 0.0015 | 5.6111 | 1.1071 | 2.4872 | 184.3190 | 12.0245 | 3449.1 |
| 13 | 0.0010 | 4.9438 | 1.2541 | 2.2377 | 141.8153 | 10.7419 | 3681.64 |
| 14 | 0.0004 | 4.8571 | 1.2047 | 2.2491 | 149.5314 | 11.1405 | 5358.91 |
| 15 | 0.0005 | 7.3226 | 1.1630 | 2.7244 | 353.4527 | 11.4776 | 25885.69 |
| 16 | 0.0017 | 6.0000 | 1.0588 | 2.4208 | 207.6509 | 12.5260 | 31860.73 |
| 17 | 0.0002 | 6.5000 | 1.0568 | 2.5548 | 323.1033 | 12.5228 | 27322.27 |
| 18 | 0.0002 | 3.6429 | 0.9424 | 1.6956 | 98.5086 | 14.0226 | 24329.44 |
| 20 | 0.0013 | 4.2899 | 1.0653 | 1.9835 | 243.5897 | 12.5155 | 3805.69 |
| 21 | 0.0030 | 5.1176 | 1.2059 | 2.0166 | 157.9207 | 11.2123 | 3901.12 |
| 22 | 0.0010 | 4.2283 | 1.2701 | 2.1110 | 170.5284 | 10.6468 | 2831.66 |
| 23 | 0.0016 | 4.2917 | 1.2585 | 2.0891 | 140.5402 | 10.7391 | 2521.93 |
| 24 | 0.0016 | 4.7947 | 1.2615 | 2.2438 | 157.4365 | 10.7262 | 4198.01 |
| 25 | 0.0003 | 4.4105 | 1.0878 | 2.1102 | 222.6500 | 12.1240 | 2796.32 |
| 26 | 0.0003 | 4.2166 | 1.0429 | 2.0685 | 166.8000 | 12.7324 | 9989.719 |
| 27 | 0.0002 | 4.5913 | 0.9802 | 2.1332 | 191.2473 | 13.4729 | 2512.34 |
| 28 | 0.0003 | 3.1915 | 0.8732 | 1.6281 | 216.2263 | 14.9919 | 2067.08 |
| 29 | 0.0009 | 3.1026 | 0.7867 | 1.4342 | 378.7852 | 16.9271 | 2276.04 |
| 30 | 0.0007 | 3.3625 | 1.1476 | 1.6379 | 323.5666 | 11.7128 | 2445.72 |
| 31 | 0.0005 | 3.2869 | 1.0694 | 1.5687 | 219.2239 | 12.5194 | 7083.27 |
| 32 | 0.0006 | 3.4540 | 1.1931 | 1.8216 | 207.1198 | 11.2991 | 2981.17 |

| Zone | Choice [Norm] | Connectivity | Integration [HH] | Integration [HH] R3 | Real Line Length (m) | Mean Depth | Block size (m²) |
|---|---|---|---|---|---|---|---|
| 33 | 0.0003 | 3.2590 | 1.0297 | 1.6995 | 170.5719 | 12.9497 | 6079.91 |
| 34 | 0.0006 | 3.9036 | 1.2187 | 1.9961 | 265.5602 | 11.0946 | 3136.96 |
| 35 | 0.0002 | 3.8333 | 1.1276 | 2.0670 | 209.3157 | 11.8584 | 3588.68 |
| 36 | 0.0004 | 3.0301 | 1.1673 | 1.6283 | 240.3987 | 11.5662 | 4350.93 |
| 37 | 0.0007 | 4.7661 | 1.1963 | 2.1833 | 229.6599 | 11.2549 | 9320.34 |
| 38 | 0.0006 | 4.5625 | 1.2831 | 2.1723 | 198.3946 | 10.5332 | 16943.1 |
| 39 | 0.0005 | 3.8867 | 1.2569 | 2.0228 | 168.2896 | 10.7944 | 6263.25 |
| 40 | 0.0011 | 3.5479 | 1.2618 | 2.0374 | 170.1651 | 10.7812 | 2052.53 |
| 41 | 0.0002 | 3.7875 | 1.2098 | 2.0665 | 245.1301 | 11.0914 | 1870.56 |
| 42 | 0.0010 | 4.2795 | 1.1237 | 1.9947 | 221.2685 | 11.9121 | 2413.42 |
| 43 | 0.0011 | 3.7113 | 1.2059 | 1.9574 | 250.1877 | 11.2657 | 1178.29 |
| 44 | 0.0004 | 3.7917 | 1.0999 | 1.8813 | 184.8158 | 12.1379 | 1255.09 |
| 45 | 0.0020 | 4.3552 | 1.0793 | 2.0449 | 237.7500 | 12.3487 | 1958.53 |
| 46 | 0.0006 | 3.5645 | 1.0040 | 1.6165 | 215.6758 | 13.2582 | 949.118 |
| 47 | 0.0004 | 3.1080 | 1.0398 | 1.6183 | 184.9293 | 12.7870 | 3742.59 |
| 48 | 0.0014 | 3.2157 | 0.9156 | 1.5089 | 592.6704 | 14.7485 | 1044.73 |
| 49 | 0.0007 | 2.8010 | 0.9097 | 1.4235 | 466.1759 | 14.6240 | 2942.76 |
| 50 | 0.0057 | 3.9189 | 1.1368 | 1.7778 | 590.0294 | 11.8140 | 1081.844 |
| 57 | 0.0005 | 4.9262 | 1.2511 | 2.2155 | 798.5595 | 10.8255 | 4732 |
| 61 | 0.0004 | 3.7611 | 0.8569 | 1.7177 | 256.6929 | 15.3554 | 1013.69 |
| 63 | 0.0007 | 3.1268 | 0.8972 | 1.5561 | 189.4674 | 14.6896 | 933.1 |
| 64 | 0.0009 | 2.8148 | 0.9122 | 1.4600 | 157.8456 | 14.5586 | 1144.77 |
| 65 | 0.0004 | 2.8947 | 0.8786 | 1.4972 | 181.6037 | 14.9557 | 2099.155 |
| 66 | 0.0009 | 3.2959 | 0.7865 | 1.5758 | 136.7114 | 17.1073 | 3729.97 |
| 67 | 0.0006 | 2.9894 | 0.9444 | 1.5546 | 192.7598 | 14.0228 | 298.24 |
| 68 | 0.0005 | 3.7033 | 1.0046 | 1.7940 | 218.9463 | 13.2384 | 260.9 |

# 5. Discussion

This study examined whether planning-zone-level urban configuration aligns with the spatial distribution of non-communicable disease (NCD) prevalence across Doha, using an ecological framework that integrates space syntax measures with GIS-based spatial analysis. Rather than reiterating mapped results, the Discussion interprets how observed spatial patterns may plausibly relate to configurational characteristics and situates these findings within the broader urban-health literature.

# 5.1 Disease-Specific Spatial Patterns of NCDs Across Doha

The results demonstrate that spatial patterning varies by health outcome, underscoring the importance of avoiding a single, uniform interpretation of built-environment effects. Obesity and hypertension exhibited significant positive spatial autocorrelation, indicating non-random clustering at the zone level. These findings are consistent with international evidence showing that cardiometabolic outcomes tend to align with neighbourhood environments that constrain routine physical activity, particularly in car-dependent urban contexts (Giles-Corti et al., 2016; Fazeli Dehkordi et al., 2022).

In Doha, zones with elevated overweight and obesity prevalence frequently overlap with areas characterised by coarser urban grain, larger blocks, and lower levels of network integration. Similar associations between reduced connectivity, limited route choice, and higher obesity risk have been observed in other settings, including Japan and European cities, where street layout influences walking propensity and sedentary behaviour (Koohsari et al., 2017; Andrees et al., 2024). However, the present findings extend this literature by demonstrating that such spatial alignments are observable even at an aggregated planning-zone scale within a hot-arid, automobile-oriented Gulf city.

COPD displayed the strongest spatial clustering signal among the analysed outcomes, but with a spatial logic distinct from cardiometabolic conditions. Zones with elevated COPD prevalence were more consistently associated with large block sizes, deeper network hierarchies, and proximity to major vehicular corridors. This pattern aligns with emerging spatial-epidemiological evidence suggesting that respiratory outcomes may be more sensitive to exposure-related pathways, including traffic concentration and corridor effects, rather than to walkability constraints alone (Andrees et al., 2024). While air-quality data were not available, the differentiated spatial signature of COPD supports a multi-pathway interpretation of built-environment–health relationships.

In contrast, diabetes and cardiovascular disease showed weaker and statistically non-significant global clustering. This divergence is consistent with prior studies indicating that these outcomes may be more strongly mediated by long-term behavioural, demographic, and clinical factors that are not fully captured by neighbourhood morphology alone (Fazeli Dehkordi et al., 2022). The absence of strong morphological alignment therefore represents an informative finding rather than a limitation.

# 5.2 Urban Configuration as a Differentiated Health Exposure Context

Interpreted collectively, the findings support the conceptualisation of urban configuration as a differentiated exposure context rather than a deterministic driver of health outcomes. Configurational measures—such as integration, connectivity, mean depth, and block size—appear most relevant for outcomes closely tied to daily mobility and incidental physical activity, particularly obesity and hypertension. This interpretation aligns with space-syntax-informed urban health research demonstrating that relational street structure influences movement potential, exposure, and behavioural opportunity beyond what is captured by density or land-use indicators alone (Vaughan & McEachan, 2024).

At the same time, the presence of interpretive exceptions highlights the limits of morphology-only explanations. Zone 66, for example, exhibits elevated obesity prevalence despite being widely perceived as a high-amenity environment. Importantly, this zone includes not only The Pearl development but also substantial portions of Zone 65 and 66, suggesting internal heterogeneity in both urban form and population composition. Such cases reinforce findings from other contexts that neighbourhood configuration interacts with demographic composition, mobility beyond the residential zone, and lifestyle factors, rather than operating in isolation (Leyden, 2003; Burton et al., 2011).

Compared with international studies, the Doha case underscores the importance of climatic and cultural context. In hot-arid environments, even moderately walkable configurations may fail to translate into routine physical activity if thermal comfort, shading, or destination mix are inadequate. This contextual sensitivity helps explain why configurational disadvantage aligns strongly with some outcomes while remaining weak or inconsistent for others, and it highlights the need for climate-responsive interpretations of walkability and accessibility in Gulf cities.

## 5.3 Planning and Policy Implications

The findings highlight that urban configuration functions as a differentiated exposure context rather than a uniform determinant of health across Doha's planning zones. Zones where elevated cardiometabolic burden coincides with coarse urban grain, low network integration, and reduced permeability—particularly across parts of the central–southern belt—represent priority areas for targeted urban intervention. In these contexts, planning strategies that shorten block lengths, improve mid-block connectivity may reduce everyday walking friction and enhance movement potential, thereby supporting incidental physical activity under hot-arid conditions.

For respiratory outcomes such as COPD, the spatial logic differs. Zones exhibiting clustered prevalence alongside large blocks and corridor-oriented network structures point to exposure-oriented intervention priorities, including mitigation of traffic-related emissions, buffering of residential areas from major arterials, and improved micro-scale street design along high-movement corridors. These findings suggest that health-responsive planning must differentiate between mobility-supportive and exposure-mitigating strategies, rather than relying on a single walkability paradigm.

Importantly, high-amenity zones that nevertheless exhibit elevated obesity prevalence—such as Zone 66—underscore the limits of morphology-only solutions. In such contexts, configurational advantages may coexist with lifestyle, demographic, and behavioural factors that shape health outcomes beyond neighbourhood form. Planning responses in these areas should therefore be integrated with complementary public-health strategies addressing food environments, travel behaviour beyond the residential zone, and indoor lifestyle patterns.

# 6. Conclusion

This study examined whether Doha's street-network configuration aligns with the spatial distribution of NCD prevalence at the planning-zone scale. By integrating space syntax measures with GIS mapping and spatial autocorrelation, the findings show that urban morphology functions as a measurable exposure context that varies substantially across the municipality. Weight-related outcomes and hypertension exhibited the clearest spatial structure and were more frequently observed in zones characterised by coarser grain and weaker integration—conditions that plausibly increase local walking friction and reinforce car dependence. COPD displayed the strongest clustering signal and aligned more consistently with large-block, corridor-oriented environments, supporting an exposure interpretation linked to traffic intensity. Diabetes showed no consistent morphological pattern at the zone scale, suggesting that some outcomes may be more strongly shaped by non-spatial determinants. Zone 66 further highlights this nuance: a high-amenity setting may still fall within a higher obesity category, suggesting that configuration interacts with resident composition, mobility beyond the neighbourhood, and other unmeasured exposures.

Planning implications follow directly. Zones where low integration and large blocks coincide with elevated cardiometabolic prevalence represent priorities for permeability upgrades and climate-responsive pedestrian infrastructure. Areas with clustered COPD prevalence warrant exposure-oriented measures that reduce corridor effects and traffic-related emissions. Embedding configurational indicators in municipal planning review can help identify spatial vulnerabilities early and support health-oriented development.

Collectively, embedding space syntax indicators within municipal planning review processes can help identify spatial vulnerabilities early, prioritise intervention zones, and tailor design responses to outcome-specific health pathways. This approach aligns with Qatar National Vision 2030 and the National Master Plan's emphasis on health-supportive, walkable communities, while acknowledging the climatic and cultural constraints that shape everyday mobility in Gulf cities

While the study offers valuable insights, limitations should be acknowledged. Health data were available only at the planning zone level, which limits the precision of spatial analyses and may obscure micro-scale variations in exposure or built-environment quality. The relatively small number of zones (50) limits the application of inferential statistical models, resulting in a primarily descriptive spatial approach. Additionally, the lack of air-quality monitoring, socio-behavioural data, and microclimate information

limits our ability to disentangle non-spatial factors influencing disease patterns, particularly for conditions such as diabetes and COPD. These constraints mean the findings primarily reflect area-scale patterns rather than individual causal mechanisms.

Future research should extend this work by integrating environmental exposure datasets, fine-grained pedestrian infrastructure audits that respect patient confidentiality, and individual mobility traces to refine our understanding of how spatial configurations influence health. Longitudinal or multi-scalar studies would also help clarify temporal dynamics and strengthen the evidence base for morphology-responsive planning in hot-arid contexts. Despite its limitations, this study provides a foundational health assessment of Doha's urban spatial network and demonstrates the value of configurational analysis in informing targeted, health-supportive urban planning strategies.

# Abbreviations

NCDs
Non-Communicable Diseases
SDH
Social Determinants of Health
PHCC
Primary Health Care Corporation
IRB
Institutional Review Board
COPD
Chronic Obstructive Pulmonary Disease
HH
Hillier–Hanson Normalisation
LISA
Local Indicators of Spatial Association
PSA
Planning and Statistics Authority
SDI
Socioeconomic Deprivation Index

# Declarations

### Ethics approval and consent to participate

Ethical approval for this study was obtained from the Institutional Review Board (IRB) of the Primary Health Care Corporation (PHCC), Qatar (IRB Reference: BUHOOTH-D-25-00056). The study used anonymised, aggregated zone-level secondary data extracted from the electronic health record system. No identifiable individual-level data were accessed.

The requirement for individual informed consent was formally waived by the PHCC IRB because the study involved secondary analysis of anonymised data and presented minimal risk to participants, in accordance with national health research regulations and the principles of the Declaration of Helsinki.

### Consent for publication

Not applicable.

### Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to ethical and legal restrictions related to patient confidentiality and data licensing agreements with the Primary Health Care Corporation (PHCC), Qatar.

Data are available from the corresponding author upon reasonable request and with permission of PHCC.

### Competing interests

The authors declare that they have no competing interests.


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### Authors' contributions

HJ conceived, supervised and reviewd the study. MOS conducted the spatial analysis, generated the maps and graphs, performed data integration and statistical analysis, and drafted the manuscript. MDM contributed to the interpretation of the space syntax analysis and methodological refinement. ASA contributed to clinical data acquisition and epidemiological interpretation. RA contributed to revision of the manuscript. All authors reviewed, edited, and approved the final manuscript.


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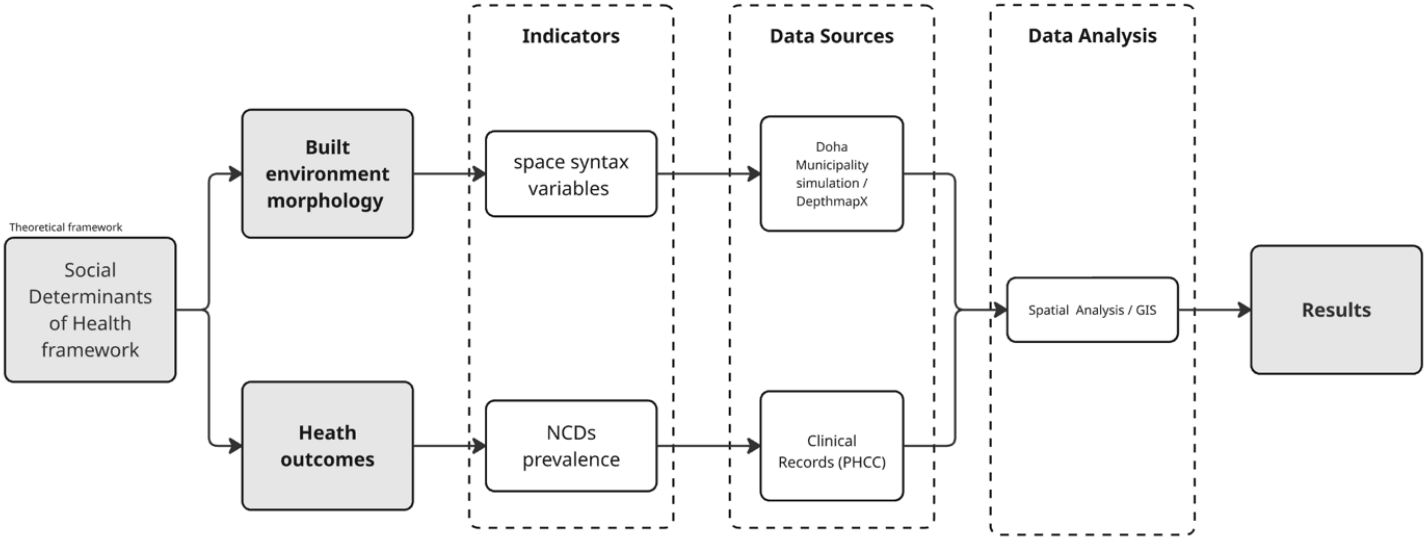
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# Figures



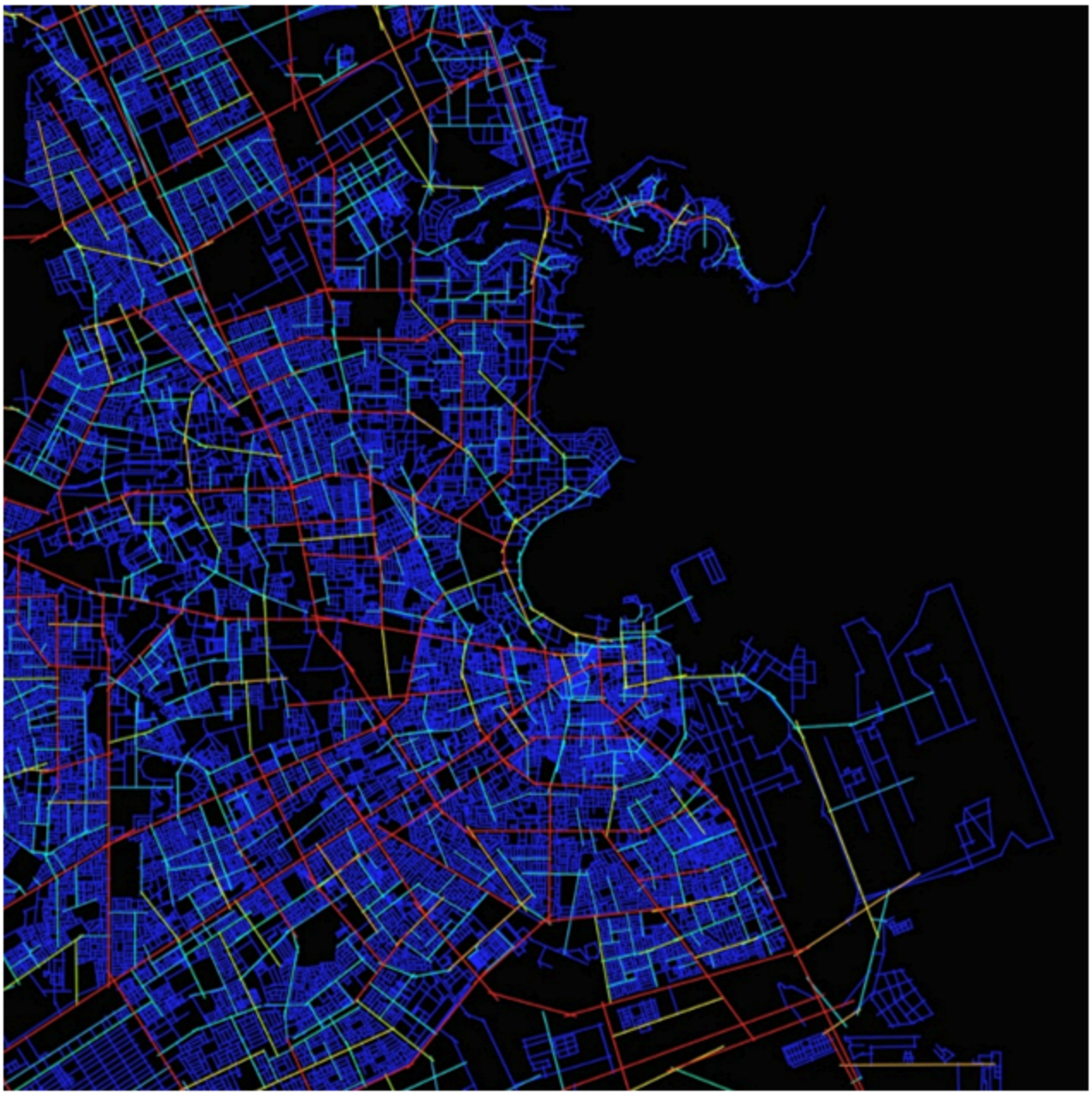

## Figure 1

(a) Qatar within the Gulf region; (b) Planning and Statistics Authority (PSA) planning zones in Doha Municipality (N=56), of which 50 zones were included in analysis after excluding zones with residential population < 100 (excluded zones shown in black). All layers projected to WGS 84/ UTM Zone 39N (Basemap source: © Esri & partners/Data source: PSA boundaries and zone layers/Qatar Open Data Portal 2024/Authors).



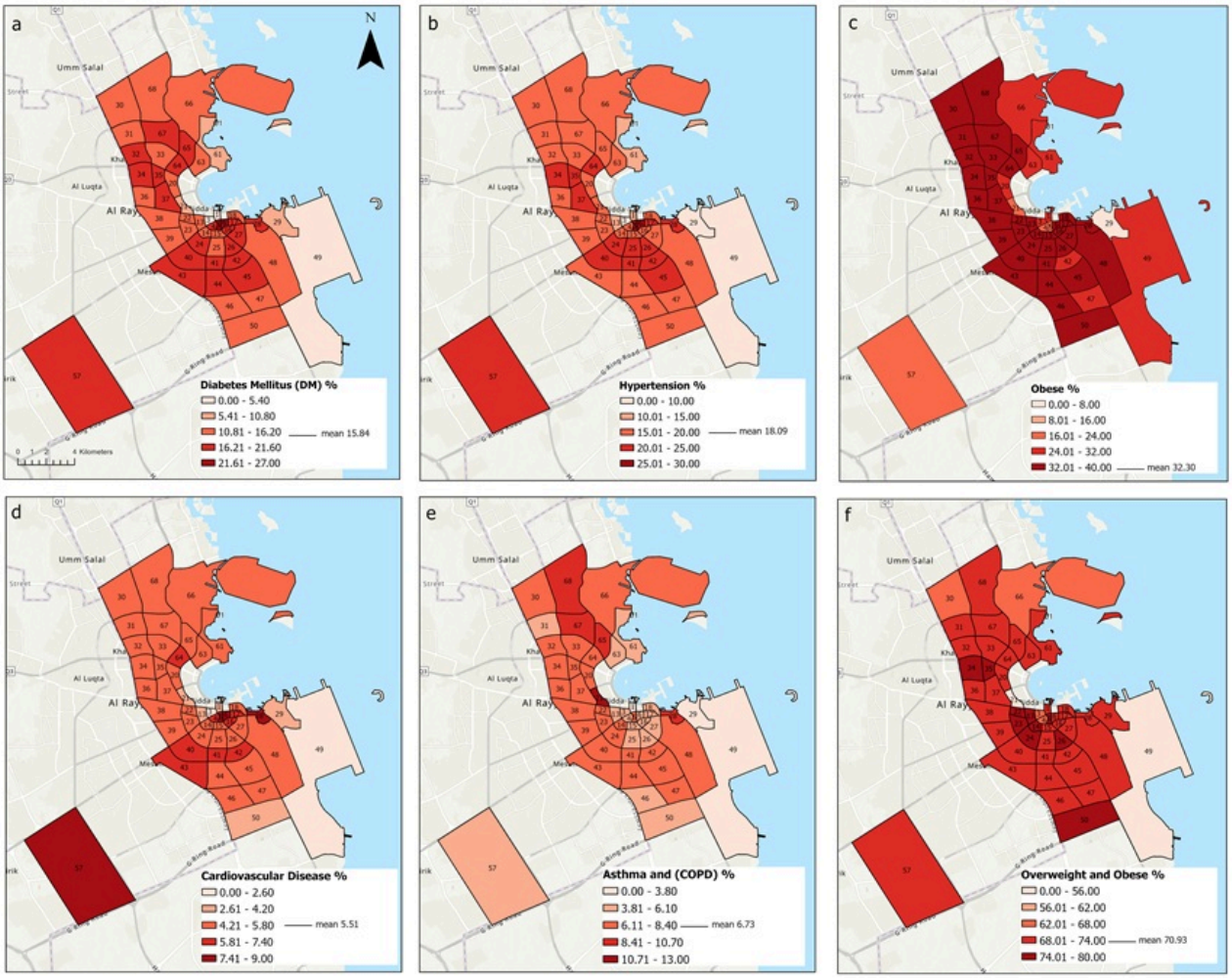

## Figure 2

Diagram outlining the research design based on the Social Determinants of Health (SDH) model (Source: Authors)



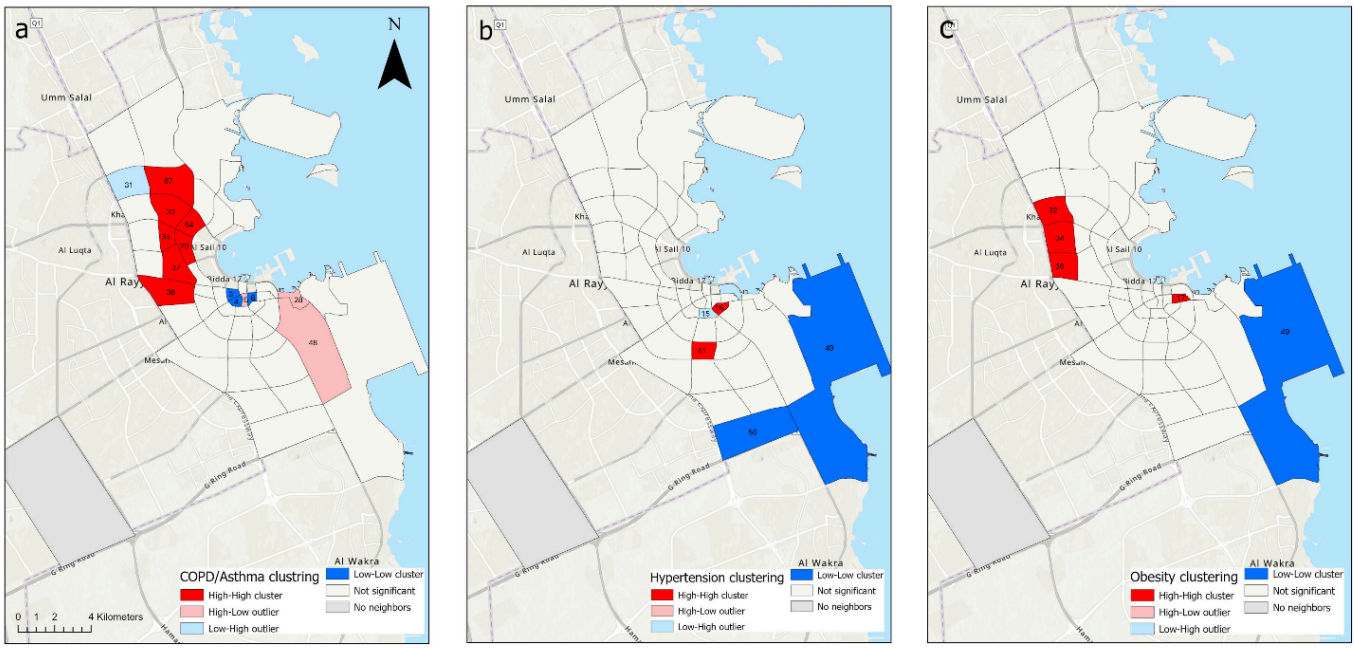
## Figure 3

DepthmapX street-network model used for space syntax analysis. Axial line representation of Doha’s street network prepared in DepthmapX and used to compute integration, choice, and connectivity prior to zone-level aggregation (Source: Authors)



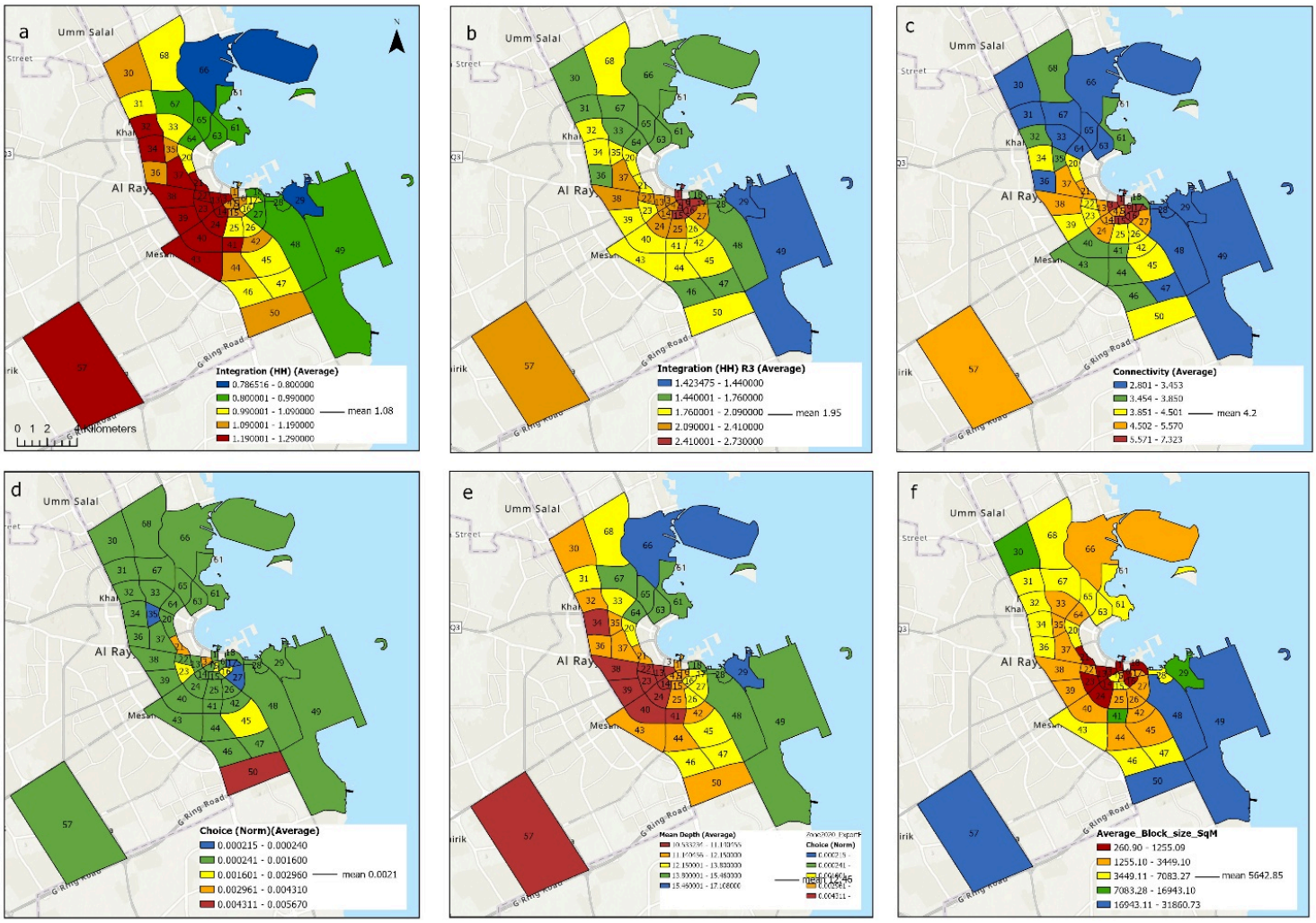

## Figure 4

Spatial distribution of non-communicable diseases (NCDs) across Doha zones. Choropleth maps represent percentage prevalence per zone for (a) Diabetes Mellitus, (b) Hypertension, (c) Obesity, (d) Cardiovascular Disease, (e) Chronic Obstructive Pulmonary Disease (COPD), and (f) Overweight and Obesity. Redder tones indicate higher prevalence (Source: Maps created by the authors using ArcGIS Pro. Basemap source: © Esri & partners).



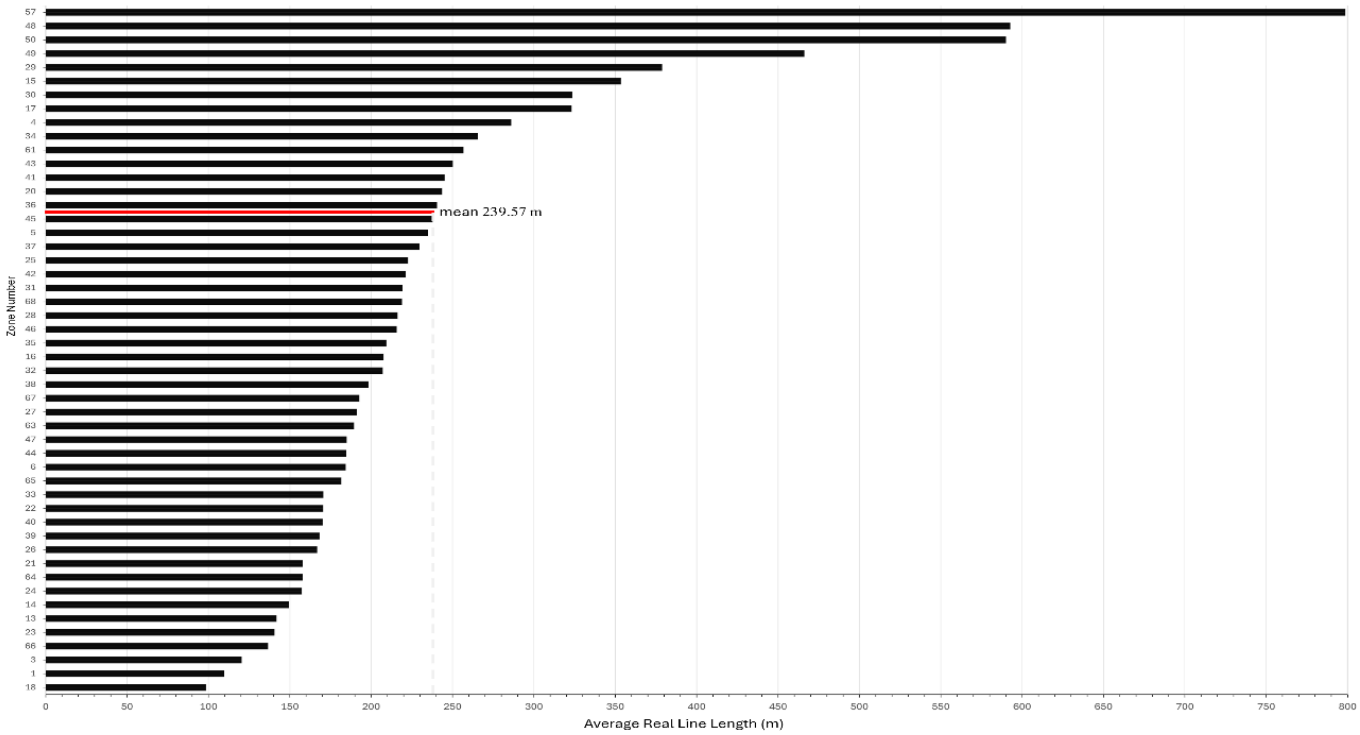

## Figure 5

Local Spatial Autocorrelation (LISA) of Major NCDs Across Zones in Doha (a) COPD (b) Hypertension, (c) Obesity across the zones of Doha (Source: Maps created by the authors using ArcGIS Pro/Basemap source: © Esri & partners).




## Figure 6

Spatial Configuration Metrics Across Zones in Doha: (a) Global Integration (HH), (b) Local Integration (HH R3), (c) Connectivity (Average), (d) Normalised Global Choice (Average), (e) Mean Depth (Average), and (f) Block size (Average) (Source: Maps created by the authors using ArcGIS Pro/Basemap source: © Esri & partners).




## Figure 7

Metric Line Length Across Zones in Doha (Source: Authors).