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# From Barriers to Connections Community Severance and Urban Connectivity in Dubai's Deira Districts: A Network Approach to Measuring, Mapping, and Reducing the Barrier Effect of Major Roads

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**ABSTRACT**

Major roads connect a city at one scale and divide it at another. The barrier effect of transport infrastructure on local movement, known as community severance, has been recognized since Appleyard and Lintell's San Francisco streets study. This effect has since been linked to reduced walking, weaker social ties, and poorer access to services, yet it is rarely measured in cities where road construction is most rapid. This paper develops and demonstrates a network method for measuring, mapping, and reducing severance in Dubai's Deira districts, where 27 communities defined by Dubai Municipality are separated by expressways, arterials, and the Creek. Two instruments are introduced. The Barrier-to-Bridge Connectivity Framework (BBCF) sequences barrier inventory, permeability scoring, network modeling, and intervention prioritization in a loop that re-scores the network after each investment. The Community Severance and Permeability Index (CSPI) combines a community's permeability-weighted boundary, its impedance-weighted detour ratio, and its expressway boundary share into a single score. Communities are treated as nodes, and shared boundaries as edges of a graph whose weights depend on barrier class and crossing provision. Betweenness and closeness centrality, effective-distance ratios, and a Gini coefficient of closeness describe the structure. A Monte Carlo simulation of 4,000 short cross-boundary trips and a negative binomial model of daily crossings on 66 barrier segments quantify the behavioral consequences. Because crossing inventories and pedestrian counts were not available, permeability scores, crossing counts, and trips are illustrative, and the results are presented as a reproducible template. On this template, expressway boundaries reduce the share of trips walked to 21%, compared to 93% across local streets. The Al Twar, Al Khabaisi, and Al Nahda communities are the most severed. Crossing spacing and the presence of a formal crossing are the dominant predictors of crossings lowers the mean CSPI by 9 points. This method provides the Roads and Transport Authority and Dubai Municipality a way to rank crossing investments by the connectivity they restore.

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## Introduction

A city that builds roads quickly also builds barriers quickly. Every expressway that shortens a journey across Dubai lengthens a journey across the street for the people living on either side. This happens silently because the pedestrians who no longer cross are not included in any traffic count. Transport planners have a term for this effect: community severance. A body of literature, tracing back to Appleyard and Lintell's (1972) comparison of three San Francisco streets, describes how residents of a heavily trafficked street had a third of the friends and acquaintances on their block compared to residents of a quiet street. Mindell and Karlsen's (2012) systematic review confirmed that traffic speed and volume reduce physical activity, social contact, children's play, and access to goods and services. They noted that the health consequences of severance had never been directly tested. A decade later, Higgsmith and colleagues (2022) provided that test with a national survey in which a community severance index predicted poorer self-rated health after adjustment for age, income, and employment.

Dubai presents an instructive setting for three reasons. Its road network was built in a few decades, establishing a hierarchy that places expressways with eight or more lanes between residential communities. This makes severance structural rather than incidental. Its older districts in Deira, laid out before the expressway era, retain a fine street and alley grain that Alawadi, Alameri, and Scoppa (2023) showed improves pedestrian route directness where it survives. This sharpens the contrast between what the neighborhood offers internally and what the boundary permits. Furthermore, its authorities are investing heavily in the road network while committing, under the Dubai 2040 plan, to a walkable city where residents reach most needs on foot. A method that scores the connectivity cost of a barrier and the connectivity return of a crossing speaks directly to both programs.

The paper is organized as a demonstration. Section 2 reviews existing knowledge on severance, accessibility, and street-network structure. Section 3 introduces the Barrier-to-Bridge Connectivity Framework and the Community Severance and Permeability Index. Section 4 describes the Deira cluster, the data, and the models. Section 5 reports the results: the barrier inventory, the community ranking, the network structure, the trip simulation, and the crossing model and scenarios. Section 6 discusses the implications of the results for Hor Al Anz and its neighbors, for connectivity equity, and for the road program. Section 7 outlines recommendations, and Sections 8 and 9 present limitations and conclusions. Community boundaries are real and official; the permeability of each boundary, and all subsequent findings, are illustrative until the crossing inventory in Appendix B is completed.

### Questions and Contributions

The study addresses four primary questions:

Which boundaries between Deira's communities function as barriers, and what type of barriers are they?

How severed is each community, considering boundary permeability, and how is this severance unequally distributed?

What impact does a barrier have on short trips that would otherwise cross it, and which boundary design attributes predict the number of people who cross?

Which crossing investments restore the most connectivity, and for whom? The contributions of this research include:

A framework (BBCF).

An index (CSPI).

A community-graph method that operates on the official boundary layer.

A trip simulation and a count model that link design to behavior.

A scenario procedure for ranking investments.

All these components are delivered as a scripted pipeline, ensuring that the inventory, once finalized, produces measured rather than illustrative results.

## Community Severance, Accessibility, and Network Structure

### The Barrier Effect and Its Measurement

Anciaes, Jones, and Mindell (2016) decomposed the severance problem into a sequence of questions: where it occurs, whom it affects, how it changes behavior, and what it costs. They reviewed the available methods for each, concluding that severance is seldom quantified in project appraisal and almost never valued. Their companion paper (Anciaes, Boniface, Dhanani, Mindell & Groce, 2016) presented a cross-disciplinary research agenda where the barrier is treated not only as a physical object but also as a psychological one, deterring trips that are possible in principle. Mindell and colleagues (2017) tested a suite of tools on a single London corridor, triangulating street audits, a household survey, spatial analysis, and participatory mapping. They found agreement on where severance was severe but differed on how much was attributable to design versus traffic. Anciaes, Jones, and Metcalfe (2018) addressed the valuation gap with a stated-preference model that assigns a monetary value to reductions in severance and to the quality of crossing facilities, with grade-separated crossings valued lowest by pedestrians due to the detour and climb they impose.

The health pathway associated with severance operates through walking and social contact. Egan, Petticrew, Ogilvie, and Hamilton's (2003) systematic review of new roads indicated that bypasses tend to reduce severance in towns they relieve, while major urban roads increase it in the neighborhoods they cut. Mouratidis (2018) demonstrated that urban form shapes social life through the frequency and ease of encounters, which severed boundaries suppress. These findings support treating a boundary's permeability, not just its traffic, as a design outcome.

### Accessibility and Detour

Accessibility serves as the natural currency for understanding severance. Handy and Niemeier (1997) and Geurs and van Wee (2004) outlined various accessibility measures, from cumulative opportunities to gravity and utility-based indices. The latter emphasize that a measure must be sensitive to the transport component—the effort required to reach an opportunity, not just its existence. For a pedestrian, the effort imposed by a barrier is the detour to the nearest crossing plus any delay at it. A measure that ignores the barrier will overstate the accessibility of destinations on the far side. Evidence on travel and the built environment, assembled by Cervero and Kockelman (1997) and Ewing and Cervero (2010), identifies design, particularly street network connectivity, as a reliable correlate of walking. Intersection density and route directness are commonly used proxies.

### Street Networks as Graphs

Porta, Crucitti, and Latora (2006) established the primal representation of street networks, wherein intersections are nodes and street segments are edges. They showed that centrality indices computed on such graphs capture a city's structural skeleton. Boeing (2017) made this approach scalable with OSMnx. The present study uses a coarser graph, where communities are nodes and shared boundaries are edges. This focuses on the boundary itself, allowing for manageable computation and visual reasoning. This graph maps directly onto the administrative units used by Dubai Municipality. The two representations are complementary: the community graph highlights important boundaries, while a street-level graph could pinpoint crossing locations.

### Dubai's Neighborhoods

Alawadi (2017) traced how Dubai's neighborhood form evolved from compact, connected fabrics to superblocks bounded by high-speed roads, advocating for form-based strategies to recover integration. Alawadi, Alameri, and Scoppa (2023) quantified the internal aspects of this trend, showing that across eleven Dubai neighborhoods, pedestrian route directness declined over successive growth periods, with alleyways, where preserved, recovering some of the loss. Alawadi, Khaleel, and Benkraouda (2021) extended this comparison to Abu Dhabi, documenting how block size and boundary roads influence pedestrian access. El Jallad and colleagues (2026) demonstrated the feasibility of integrated multimodal performance measurement within Dubai's data environment. Daouda (2024) concluded at a regional scale that institutional coordination, rather than technology, constrains smart-city implementation in the Middle East. What is missing from this literature is a method to score the boundary itself—specifically, a method that assesses, for each pair of neighboring communities, how permeable the road between them is and the associated cost.

### Crossing Facilities and Pedestrian Behavior

Crossings reduce severance, but not all crossings are equally effective. Stated-preference evidence from Anciaes, Jones, and Metcalfe (2018) indicates that pedestrians value signalized at-grade crossings with short waits the most. Uncontrolled crossings on fast roads were valued least, with grade-separated footbridges and underpasses falling in between. The detour and climb imposed by these structures significantly diminish their benefit, especially for older individuals and those with mobility limitations. Mindell and colleagues' (2017) street audits consistently observed that when a grade-separated crossing was the only option, people frequently crossed at grade anyway—illegally and dangerously—if the detour was substantial. The design implication, adopted in the permeability scoring, is that a crossing's contribution depends on its spacing, delay, and vertical profile. Consequently, a footbridge every kilometer on an expressway is not equivalent to a signalized crossing every 300 meters on an arterial, even if both count as one crossing per segment.

**Table 1.** a details crossing facility types and their treatment in the permeability score.

| Facility | Typical setting | Detourto | Delay at it | Vertical effort | Pedestrian | Permeability |
|---|---|---|---|---|---|---|


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| | **in the cluster** | **reach it** | | | **preference (Anciaes et al., 2018)** | **contribution used** |
|---|---|---|---|---|---|---|
| Signalisedat-grade crossing | Arterials (D80, D82) | Low–moderate | 30–90 s | None | Highest | High |
| Uncontrolled at-grade crossing | Collectorand local streets | Low | Low | None | High on slow streets; low on fast | High (slow)/ low (fast) |
| Footbridge | Expressways (E11) | High (spacing 1–4 km) | None | Two flights of stairs or ramps | Low–moderate | Low–moderate |
| Underpass | Expressways; airport edge | High | None | Descent and ascent; perceived safety | Low–moderate | Low–moderate |

| **Facility** | **Typical setting in the cluster** | **Detourto reach it** | **Delay at it** | **Vertical effort** | **Pedestrian preference (Anciaes et al., 2018)** | **Permeability contribution used** |
|---|---|---|---|---|---|---|
| No facility | Water and port edges;some expressway stretches | Very high | — | — | — | Near zero |

**Table 1.** — Literature synthesis and its use in this study.

| **Strand** | **Representative sources** | **What it establishes** | **Used here for** |
|---|---|---|---|
| Severanceand health | Appleyard & Lintell (1972); Mindell & Karlsen (2012); Egan et al. (2003); Higgsmith et al. (2022); Mouratidis (2018) | Traffic and infrastructure reduce walking, contact and, plausibly, health | Outcome layer of the framework |
| Measuringand valuing severance | Anciaes et al. (2016a, 2016b); Mindell et al. (2017); Anciaes et al. (2018) | Decompositionofthe problem;tooltriangulation;pedestrian valuation of crossing types | CSPI components; crossing-quality weights |
| Accessibility | Handy & Niemeier (1997); Geurs & van Wee (2004); Cervero & Kockelman (1997); Ewing & Cervero (2010) | Effort-sensitive access measures; design and connectivitypredict walking | Impedance-weighted distance; detour ratio |
| Network analysis | Portaetal.(2006);Boeing (2017) | Primal graphs; centrality recovers urban structure | Community adjacencygraph; centralities; Gini |
| Dubai form and connectivity | Alawadi (2017); Alawadi et al. (2021, 2023); El Jallad et al.(2026); Daouda (2024) | Superblock era reduced route directness; alleys recover part; data and institutions | Caseframing; barrier classification |


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## Framework and Index

### The Barrier-to-Bridge Connectivity Framework

The framework comprises four iterative stages:

Barrier Inventory: Records each shared boundary between communities, classifying it by type (expressway, arterial, collector, local street, water or port edge), length, design speed, and crossing spacing.

Permeability Scoring: Converts these attributes into a permeability score (π) ranging from 0 to 1. This score represents the probability that a pedestrian wishing to cross at a random point can do so with acceptable detour and delay. Factors like grade separation, signal timing, and crossing quality are incorporated, potentially weighted by pedestrian valuations (Anciaes et al., 2018).

Network Modeling: Constructs the community graph, calculating impedance-weighted distances, centralities, and the CSPI. It also measures connectivity inequality across communities.

Intervention Prioritization: Tests various crossing scenarios and ranks them based on CSPI points gained per unit cost.

This loop ensures that each intervention modifies permeability, thereby influencing subsequent rankings. Underlying these stages are two layers: an evidence layer for calibrating permeability scores with crossing counts, detours, and perceptions, and an outcome layer for tracking walking share and access to amenities like parks, clinics, and transit.

### The Community Severance and Permeability Index

The CSPI (Equation 1) scores a community based on three components:

One minus the permeability-weighted boundary: Communities surrounded by impermeable roads receive higher scores.

Impedance-weighted detour ratio (ρ) (Equation 2): This is the average, across all other communities, of the ratio between the cheapest impedance-weighted path and the straight-line distance, capped to prevent extreme ratios from dominating.

Expressway boundary share: This component accounts for the additional noise, air quality, and safety costs imposed by expressways beyond the detour.

Weights of 0.40, 0.35, and 0.25 reflect the literature's emphasis on permeability as the actionable variable. Scores range from 0 (fully connected) to 100 (fully severed).

$$\mathrm{CSPI}_i = 100\left[0.40\,(1-\bar{\pi}_i) + 0.35\min\left(\frac{\rho_i - 1}{2}, 1\right) + 0.25\,\phi_i\right], \quad \bar{\pi}_i = \frac{\sum_{e\in E_i} \pi_e L_e}{\sum_{e\in E_i} L_e}$$

$$\rho_i = \frac{1}{N-1}\sum_{j\neq i}\frac{d_{ij}^{w}}{d_{ij}^{0}}, \qquad d_{ij}^{w} = \min_{P:i\to j}\sum_{e\in P}\frac{\ell_e}{\pi_e}$$

Equation 2 defines the impedance-weighted distance. It calculates the shortest path where each edge's length is divided by its permeability. Consequently, crossing an expressway with a permeability of 0.12 costs approximately eight times its length in walking effort, whereas crossing a local street with a permeability of 0.93 costs only slightly more than the distance itself. The ratio ρ, therefore, represents not a literal detour but an effective-distance multiplier. The actual detour is determined by the trip simulation in Section 4.5.

### Sensitivity of the Index to its Weights

**Table 1.** b illustrates the CSPI's sensitivity to alternative weighting schemes, using illustrative permeabilities.

| Weighting (π̄ / ρ / expressway) | Spearman ρ with paper index | Mean CSPI | Top five communities |
|---|---|---|---|
| Paper (0.40/0.35/0.25) | 1.000 | 58.1 | Al Twar Second; Al Twar |


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| | | | |
|---|---|---|---|
| | | | First; Al Khabaisi; Al Nahda First; Al Qusais Second |
| Equal | 0.993 | 54.7 | Al Twar First; Al Twar Second; Al Khabaisi; Al Nahda First; Al Qusais Second |
| Permeability-heavy | 0.969 | 56.5 | Al Hamriya Port; Al Garhoud; Al Twar Second; Al Twar First; Al Nahda First |
| Detour-heavy | 0.998 | 69.2 | Al Twar Second; Al Twar First; Al Khabaisi; Al Nahda First; Al Qusais Second |

Rank correlations with the paper's weighting scheme exceed 0.96 across all alternative schemes, and the top five communities remain largely unchanged. The exception is the permeability-heavy weighting, which elevates water-bounded communities like Al Hamriya Port and Al Garhoud to the top. This is informative rather than problematic, as it highlights the influence of water edges, distinct from roads, on their scores. A design-only variant of the index, excluding water edges, eliminates this sensitivity. Users should specify their chosen weights and, for prioritizing road crossings, employ the design-only variant.

## Study Area, Data, and Methods

### The Deira Cluster

The study encompasses 27 communities east of Dubai Creek, stretching from Al Ras and the historic Deira core through Al Rigga, Al Muraqqabat, Al Muteena, Abu Hail, and Hor Al Anz to Al Twar, Al Qusais, and Al Nahda on the Sharjah border. Communities to the south include Port Saeed and Al Garhoud, and to the north, Al Mamzar and Al Hamriya Port (Figure 1). Community boundaries are derived from the Dubai Municipality's official community boundary layer, with each community assigned an official number. Hor Al Anz is community 127, and Hor Al Anz East is community 133. The cluster features 44 shared boundaries totaling 47 kilometers. Of this total, 10.5 km are expressways, 19.3 km are arterials, 12.3 km are collector or local streets, and 4.7 km are along the Creek, port, or sea.

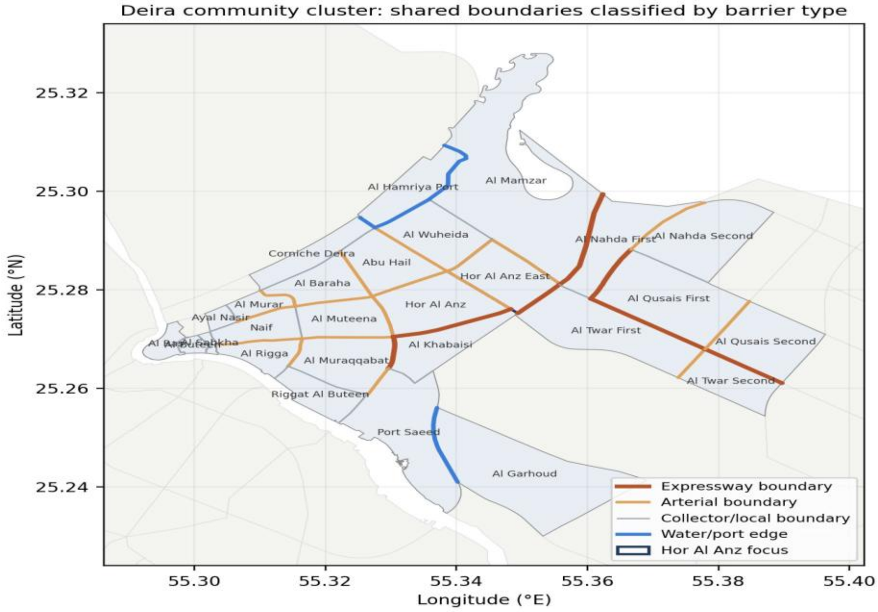



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**Figure 1.** illustrates the Deira community cluster, showing shared boundaries classified by barrier type. Boundaries represent official community polygons, and barrier classes are assigned based on public road classification, pending verification in the inventory (Appendix B).

## Barrier Classification and Permeability

**Table 2.** presents barrier classes, illustrative design attributes, and base permeability values, which are subject to replacement by inventoried data.

| Class | Examples of boundary roads in the cluster | Design speed (km/h) | Typical lanes | Formal crossings per km | Base permeability π | Edges (n) | Length (km) |
|---|---|---|---|---|---|---|---|
| Expressway | Al Ittihad Road (E11); Airport Road | 100 | 8 | 0.25 | 0.12 | 7 | 10.5 |
| Arterial | Abu Baker Al Siddique Road (D82); Salahuddin Road (D80); Al Rasheed Road; Baghdad Street | 60 | 6 | 0.9 | 0.45 | 17 | 19.3 |
| Collector / local | Internal community streetsforming boundaries | 40 | 2 | 3.0 | 0.90 | 16 | 12.3 |
| Water/ port edge | Dubai Creek; Al Hamriya Port; sea frontage | — | — | 0.1 | 0.05 | 4 | 4.7 |

Each edge's permeability was generated around its class base permeability with a 12% noise factor to reflect local variations, and its crossing spacing was determined around the class mean. These values will be replaced by the inventory data; no other part of the analysis pipeline is affected by this change.

## Network Measures


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$$G = \frac{2\sum_{k=1}^{N} k\, c_{(k)}}{N\sum_{k} c_{(k)}} - \frac{N+1}{N}$$

(4)

### Crossing Model

Daily pedestrian crossings on 66 barrier segments, approximately 800 meters long, were modeled using a negative binomial regression (Equation 3). This model considered permeability, crossing spacing, design speed, the presence of a formal crossing, and the logarithm of the adjacent population. The negative binomial model was chosen over the Poisson model because crossing counts exhibited overdispersion. Counts for the demonstration were generated from this structure with an overdispersion parameter. These counts serve to illustrate how the model isolates design levers once field counts become available.

$E[Y_j] = \exp(\beta_0 + \beta_1\pi_j + \beta_2 S_j + \beta_3 V_j + \beta_4 X_j + \beta_5 \ln P_j)$, $Var[Y_j] = \mu_j + \alpha\mu^2_j$ (3)

### Trip Simulation and Scenarios

A Monte Carlo simulation generated 4,000 short trips originating from a random community and terminating in a random adjacent community. The straight-line distance was drawn from a gamma distribution centered around 700 meters. Detours to the nearest crossing were uniformly distributed up to the crossing spacing. A ramp penalty of 350 meters was applied for grade-separated expressway crossings, and a signal delay was included for at-grade crossings. The probability of a trip being walked (rather than driven or abandoned) was modeled using a logistic function of walking time and permeability. Four scenarios modified permeability on expressway and arterial boundaries and recomputed all network measures and the CSPI: doubling expressway crossings, increasing arterial crossings by 50%, combining both, and tripling expressway permeability (representing bridges every 400 meters). All computations were scripted in Python using NetworkX, Shapely, and statsmodels.

### Validation Plan and Sample Size for the Count Survey

**Table 2.** a outlines the validation plan for replacing illustrative values with measurements.

| Element | Requirement | Basis | Implication |
|---|---|---|---|
| Crossing counts | At least 60 segments with counts on two weekdays and one weekend day | Negative binomial with fivepredictors; overdispersion | Covers all expressway and arterial segments in the cluster; collectors sampled |
| Intercept survey | About 600 pedestrians at 20 crossing points | Estimate the walking-propensity function and detour tolerance | Replaces the assumed logistic parameters in the simulation |
| Permeability calibration | Field permeability for every boundary from Appendix B fields | Section 4.2 | Replacesclass-level base values |
| Perception survey | Household survey items on | Linkstheindexto resident | Validates CSPI against |


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| | | | |
|---|---|---|---|
| | perceived difficulty of crossing (Higgsmith et al., 2022) | experience | perceived severance |
| Before-and-after | Counts and survey repeated one year after the pilot crossing | Section7,recommendation 5 | First measured CSPI change |

## Results

Community boundaries and adjacencies are accurate. Permeabilities, crossing spacings, crossing counts, and trips are illustrative. The statistics presented below demonstrate the methodology rather than measure the districts definitively.

### The Community Ranking

**Table 3.** lists the fourteen most severely affected communities based on the CSPI (using illustrative permeabilities). The complete ranking is provided in Appendix A.

| Rank | Community | No. | Boundary (km) | Permeability-weighted π̄ | Expressway share | Effective-distance ratio ρ | Betweenness | Closeness | CSPI |
|---|---|---|---|---|---|---|---|---|---|
| 1 | AlTwar Second | 227 | 2.2 | 0.23 | 0.65 | 5.28 | 0.000 | 0.036 | 82.2 |
| 2 | AlTwar First | 226 | 4.4 | 0.27 | 0.69 | 5.99 | 0.108 | 0.043 | 81.6 |
| 3 | Al Khabaisi | 128 | 3.6 | 0.32 | 0.74 | 5.15 | 0.000 | 0.063 | 80.8 |
| 4 | AlNahda First | 231 | 5.6 | 0.28 | 0.62 | 5.53 | 0.218 | 0.043 | 79.1 |
| 5 | AlQusais Second | 233 | 2.7 | 0.29 | 0.52 | 5.37 | 0.003 | 0.032 | 76.4 |
| 6 | AlQusais First | 232 | 6.1 | 0.35 | 0.56 | 6.04 | 0.074 | 0.036 | 75.1 |
| 7 | Al Hamriya Port | 131 | 3.0 | 0.05 | 0.00 | 11.21 | 0.000 | 0.025 | 73.0 |
| 8 | Al Garhoud | 214 | 1.7 | 0.06 | 0.00 | 10.71 | 0.000 | 0.020 | 72.8 |
| 9 | Al Mamzar | 134 | 6.6 | 0.31 | 0.33 | 3.68 | 0.215 | 0.072 | 70.9 |
| 10 | Hor Al Anz | 127 | 5.5 | 0.34 | 0.35 | 4.13 | 0.172 | 0.080 | 70.2 |
| 11 | Hor Al Anz East | 133 | 4.7 | 0.37 | 0.20 | 4.41 | 0.135 | 0.075 | 65.1 |
| 12 | Port Saeed | 129 | 4.2 | 0.43 | 0.00 | 3.65 | 0.114 | 0.068 | 57.9 |
| 13 | Al Wuheida | 132 | 4.9 | 0.46 | 0.00 | 4.19 | 0.292 | 0.077 | 56.7 |
| 14 | Al Muraqqabat | 124 | 4.9 | 0.56 | 0.15 | 3.47 | 0.148 | 0.077 | 56.5 |


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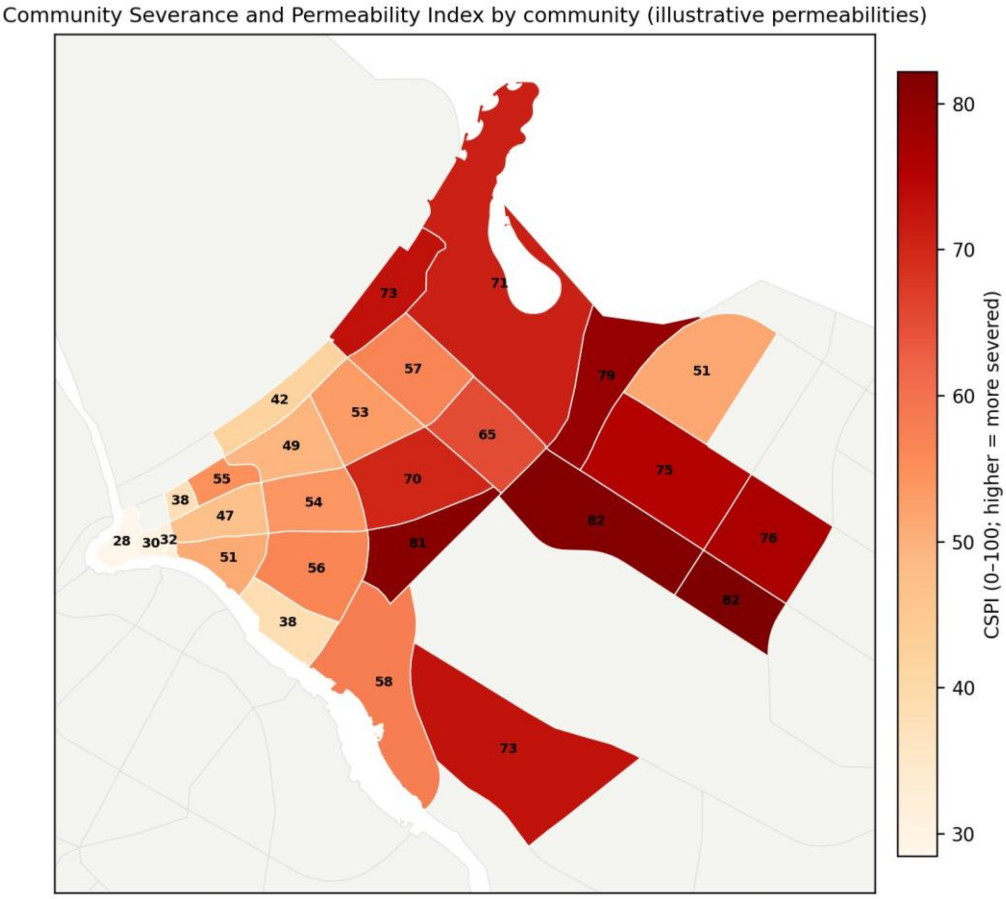


**Figure 2.** displays the Community Severance and Permeability Index (CSPI) by community, using illustrative permeabilities. Communities bordering the E11 corridor and the airport exhibit the highest scores, while the Creek-side core communities score lowest.

The ranking is heavily influenced by the E11 corridor. Al Twar Second, Al Twar First, and Al Khabaisi, whose boundaries lie along the expressway and the airport, score above 80. Al Nahda and Al Qusais, bordered by the expressway and the Sharjah border, follow. Al Hamriya Port and Al Garhoud score high for a different reason: their boundaries are water and port edges, which are inherently impermeable. The index does not differentiate between these, a point noted in the limitations. Hor Al Anz scores 70.2 and Hor Al Anz East scores 65.1. Their southern boundary with Al Khabaisi and Al Twar is an expressway. However, their northern and western boundaries with Abu Hail and Al Wuheida are arterials that can be crossed at grade, and the internal boundary between them is a local street. The Creek-side core, from Al Ras through Naif to Al Rigga, represents the least severed part of the cluster, characterized by small communities bounded by streets rather than highways.

**NetworkStructur**


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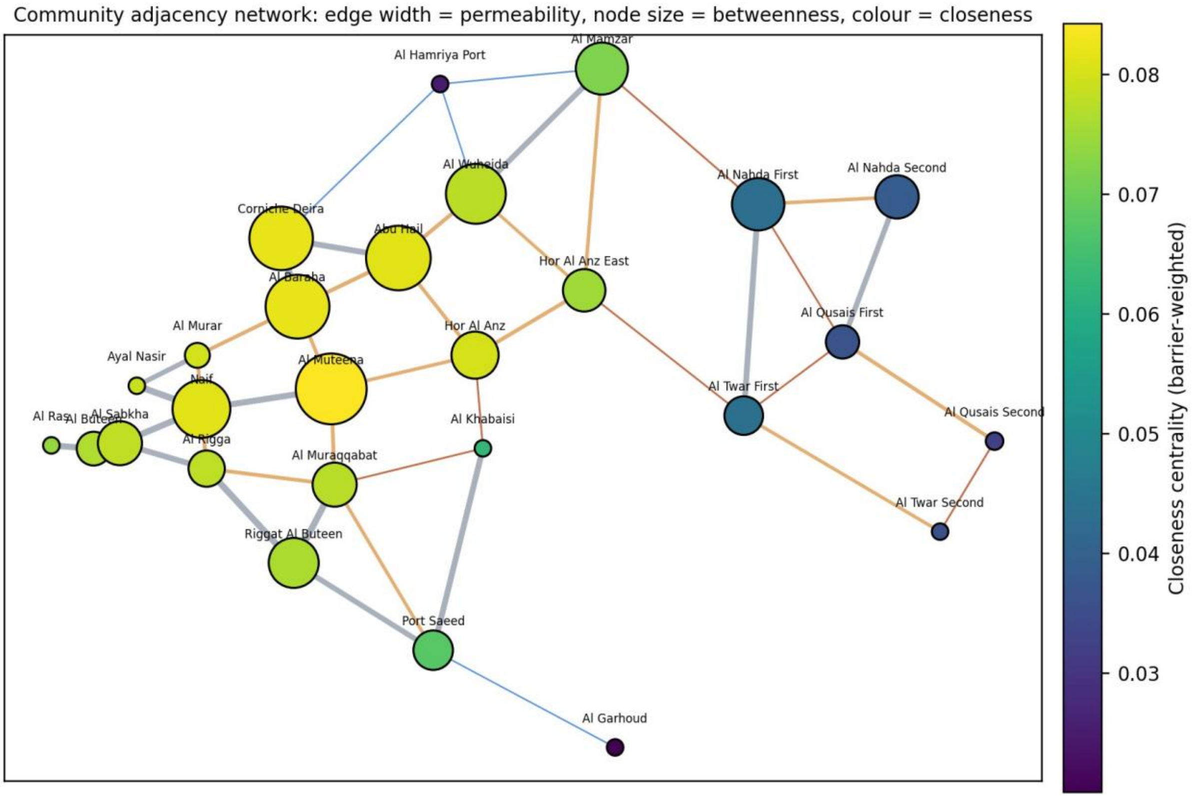


**Figure 3.** illustrates the community adjacency network. Edge width represents permeability, node size indicates betweenness centrality, and node color denotes closeness centrality on the impedance-weighted graph.

**Table 4.** presents network measures with and without barriers, based on illustrative permeabilities.

| Measure | Barrier-weighted graph | Fullypermeable comparator | Change |
|---|---|---|---|
| Mean effective-distance ratio ρ | 4.44 | 1.17 | × 3.8 |
| Gini coefficient of closeness | 0.165 | 0.118 | + 0.047 |
| Highest-betweenness community | Al Muteena | — | — |
| Highest-closeness community | Al Muteena | — | — |

Introducing barriers multiplies the mean effective-distance ratio by 3.8 and increases the Gini coefficient of closeness from 0.118 to 0.165. The latter metric is more significant. Barriers not only make the cluster harder to navigate but also distribute this difficulty unevenly, concentrating the burden on communities beyond the expressway while minimally affecting the Creek-side core. Betweenness centrality identifies communities that serve as crucial conduits for the cheapest paths between others. Opening boundaries in these locations would alleviate the most detours. Hor Al Anz

and Al Muteena are positioned on paths between the core and the eastern communities, scoring high on this measure.

## What Barriers Do to Short Trips

**Table 5.** details simulated short cross-boundary trips categorized by barrier class.

| Barrier class | Trips (n) | Median detour | 90th percentile | Median walking | Share of trips |
|---|---|---|---|---|---|


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| | | ratio | | time (min) | walked |
|---|---|---|---|---|---|
| Collector/local | 1520 | 1.17 | 1.69 | 9.1 | 93% |
| Arterial | 1355 | 1.53 | 3.12 | 13.5 | 80% |
| Expressway | 658 | 4.40 | 12.58 | 36.1 | 21% |
| Water/port edge | 467 | 8.58 | 30.75 | 70.5 | 12% |

Kruskal-Wallis test of detour ratio across expressway, arterial, and collector classes: $H = 1653$, $p < 0.001$.

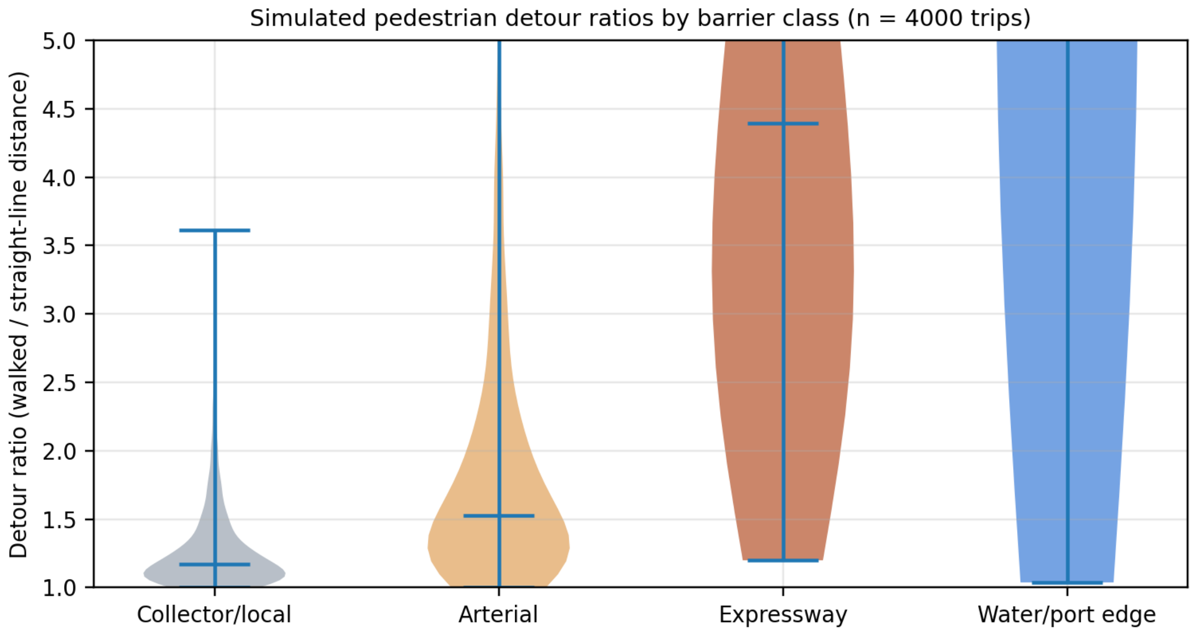


**Figure 4.** illustrates the distribution of simulated pedestrian detour ratios by barrier class. The distribution for expressways is notably higher and has a longer tail.

The simulation transforms abstract concepts into concrete data. Across a local street, the median trip is 17% longer than the straight-line distance, and 93% of trips are walked. Across an arterial, the median detour increases to 53%, and the walked share drops to 80%. Crossing an expressway results in a median trip that is 4.4 times the straight-line distance, takes 36 minutes, and is walked only 21% of the time. One in ten trips requires walking more than 13 times the direct distance. The remaining eighty percent of potential walking trips across an expressway are either driven, made by taxi, or not undertaken—this constitutes the behavioral definition of severance. Water and port edges present even greater severity, though they are not design choices.

## What Predicts Crossings

**Table 6.** shows a negative binomial regression of daily crossings per barrier segment, using illustrative counts.

| Predictor | Coefficient | SE | IRR | 95% CI | p |
|---|---|---|---|---|---|
| Permeability (0–1) | 0.374 | 0.433 | 1.45 | 0.62–3.39 | 0.388 |
| Crossing spacing (km) | -0.370 | 0.055 | 0.69 | 0.62–0.77 | < 0.001*** |
| Design speed (km/h) | -0.008 | 0.004 | 0.99 | 0.98–1.00 | 0.023* |
| Formal crossing present | 0.865 | 0.149 | 2.38 | 1.77–3.18 | < 0.001*** |
| log(adjacent | 0.259 | 0.084 | 1.30 | 1.10–1.53 | 0.002** |


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| | | | | | |
|---|---|---|---|---|---|
| population) | | | | | |

*p < 0.05, **p < 0.01, ***p < 0.001.

n = 66 segments; overdispersion α = 0.154; log-likelihood = -314.7; AIC = 643.4 (Poisson AIC 1409.5); McFadden pseudo-$R^2$ = 0.173. IRR = incidence-rate ratio.

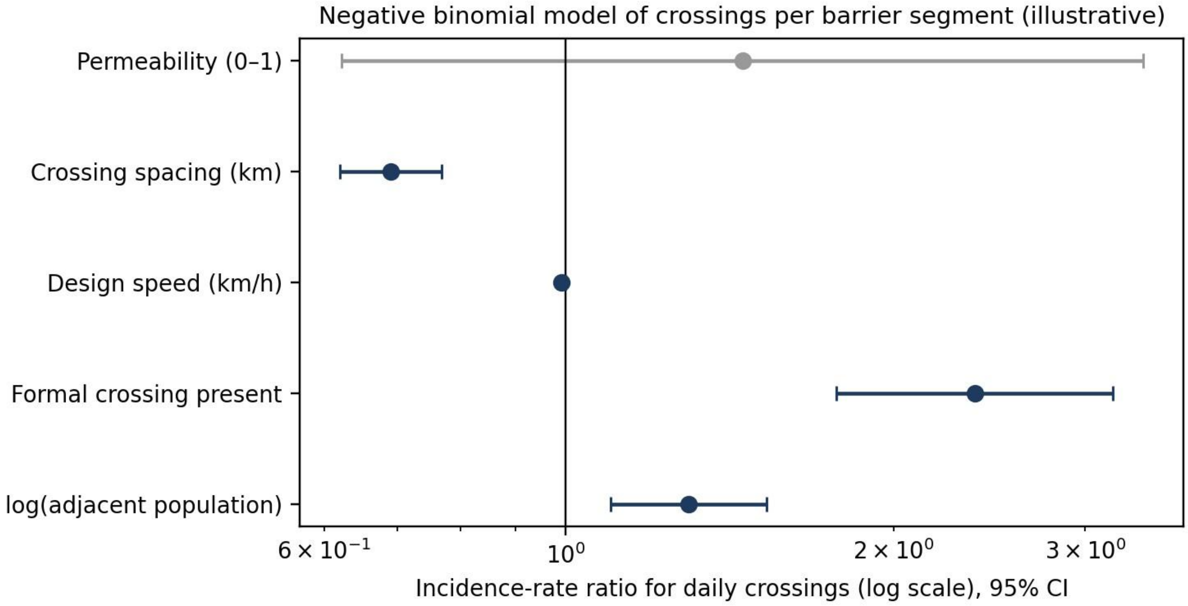


**Figure 5.** displays incidence-rate ratios from the negative binomial model with 95% confidence intervals.

Crossing spacing and the presence of a formal crossing significantly influence the model. Each additional kilometer between crossings is associated with a 31% decrease in crossings, and a formal crossing multiplies the count by 2.4, holding spacing constant. Design speed has a minor negative effect. The class-level permeability score adds little once spacing and crossing presence are included in the model, which is expected as permeability is a summary of these two variables. The model confirms the relative importance of its components. The negative binomial model provides a substantially better fit than the Poisson model, indicating that counts of this nature should not be modeled using a Poisson assumption. This implies that for the inventory, crossing spacing, which can be measured from a map in an afternoon, is the most valuable single metric.

## Scenarios

**Table 7.** presents connectivity scenarios with illustrative results.

| Scenario | Mean CSPI | Maximum CSPI | Mean effective-distance ratio | Giniof closeness | HorAl Anz CSPI | Al Khabaisi CSPI |
|---|---|---|---|---|---|---|
| Baseline | 58.1 | 82.2 | 4.44 | 0.165 | 70.2 | 80.8 |
| S1Expresswaycrossings doubled | 55.6 | 78.8 | 3.70 | 0.149 | 68.4 | 77.2 |
| S2 Arterial crossings +50% | 53.0 | 80.8 | 4.02 | 0.171 | 64.2 | 80.8 |
| S3 Both S1 and S2 | 49.2 | 77.2 | 3.33 | 0.158 | 60.3 | 77.2 |
| S4 Expressway permeability×3 (bridges every 400 m) | 53.6 | 75.5 | 3.42 | 0.140 | 66.7 | 73.6 |


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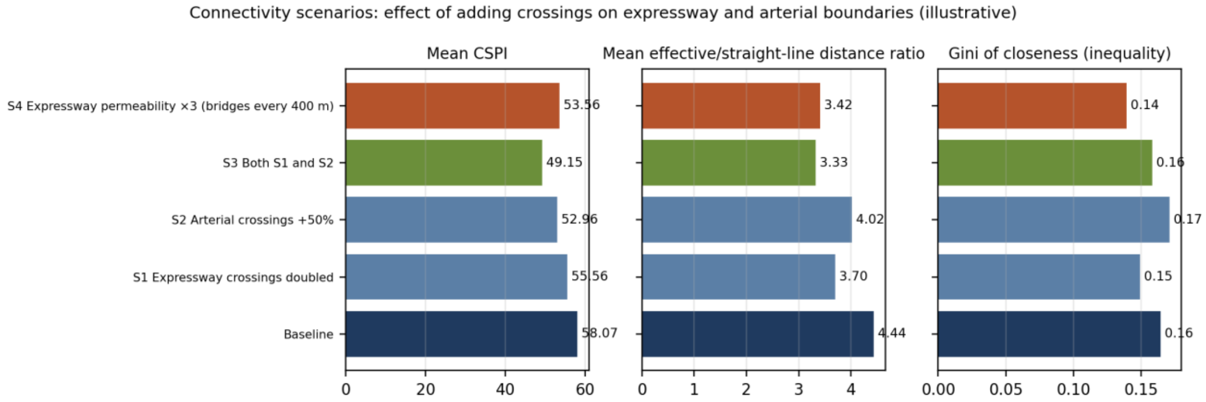


**Figure 6.** illustrates scenario results across three summary measures: mean CSPI, mean effective/straight-line distance ratio, and Gini of closeness (inequality). Expressway crossings reduce inequality, arterial crossings reduce the mean CSPI, and the combination achieves the most significant improvements in both.

The scenarios highlight two distinct benefits. Increasing expressway crossings (S1, S4) provides the greatest benefit for the effective-distance ratio and equity, as expressways involve the longest detours and have the highest concentration of severed communities. The Gini of closeness decreases from 0.165 to 0.149 in S1 and 0.140 in S4. Increasing arterial crossings (S2) yields a larger reduction in the mean CSPI, as arterials represent the most common boundary type and additional crossings are less costly. However, this approach slightly increases inequality, as the communities benefiting are already better connected. The combined program (S3) reduces the mean CSPI by 8.9 points and improves both measures. For Hor Al Anz, the CSPI drops from 70.2 to 60.3 under S3. For Al Khabaisi, across the expressway, it falls from 80.8 to 77.2.

## The Boundaries That Matter Most

**Table 7.** a ranks shared boundaries by edge betweenness on the impedance-weighted graph, using illustrative permeabilities.

| Rank | Boundary | Class | Length (km) | Permeability π | Crossing spacing (km) | Edge betweenness |
|---|---|---|---|---|---|---|
| 1 | AlBaraha–Corniche Deira | Collector/local | 1.52 | 0.98 | 0.34 | 0.348 |
| 2 | Corniche Deira – Abu Hail | Collector/local | 0.76 | 0.85 | 0.37 | 0.342 |
| 3 | Abu Hail – Al Wuheida | Arterial | 1.48 | 0.50 | 1.05 | 0.316 |
| 4 | Al Baraha – Al Muteena | Arterial | 1.21 | 0.44 | 1.34 | 0.291 |
| 5 | Naif – Al Muteena | Collector/local | 0.73 | 0.91 | 0.26 | 0.242 |
| 6 | Al Wuheida – Al Mamzar | Collector/local | 1.33 | 0.81 | 0.27 | 0.234 |
| 7 | Al Mamzar – Al Nahda First | Expressway | 2.18 | 0.12 | 3.49 | 0.217 |
| 8 | Al Nahda First – Al Nahda Second | Arterial | 1.58 | 0.43 | 1.11 | 0.199 |
| 9 | AlMuraqqabat– Al Muteena | Arterial | 1.41 | 0.48 | 0.87 | 0.179 |


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| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | Port Saeed – Riggat Al Buteen | Collector/local | 0.78 | 0.76 | 0.47 | 0.171 |
| 11 | Al Muraqqabat – Riggat Al Buteen | Collector/local | 1.39 | 0.98 | 0.29 | 0.168 |
| 12 | Hor Al Anz – Hor Al Anz East | Arterial | 1.31 | 0.49 | 1.09 | 0.168 |
| 13 | Naif – Al Sabkha | Collector/local | 0.31 | 0.95 | 0.43 | 0.154 |
| 14 | Hor Al Anz East – Al Twar First | Expressway | 0.91 | 0.12 | 2.91 | 0.142 |

Edge betweenness identifies boundaries that facilitate the most direct paths between communities. Due to the impedance-weighted graph routing around expressways, the highest betweenness edges are the permeable ones within the older core and along the Abu Hail–Al Wuheida and Al Baraha–Al Muteena arterials, which form the cluster's pedestrian spine. Expressway boundaries appear lower on this list not due to lack of importance but because they are avoided. Their significance is evident in the scenario results, where opening them shortens paths that currently go around. These two lists are complementary: high-betweenness permeable edges should be protected from permeability reduction, while low-betweenness impermeable edges between populous communities should be opened.

### a The Hor Al Anz Boundary System

**Table 7.** b details all shared boundaries of Hor Al Anz and Hor Al Anz East, including their barrier attributes (illustrative permeabilities).

| **Boundary** | **Class** | **Length (km)** | **Permeability π** | **Crossing spacing (km)** | **Design speed** | **Edge betweenness** | **Simulated walked share (class)** |
|---|---|---|---|---|---|---|---|
| Hor Al Anz – Hor Al Anz East | Arterial | 1.31 | 0.49 | 1.09 | 60 | 0.168 | 80% |
| Hor Al Anz East – Al Twar First | Expressway | 0.91 | 0.12 | 2.91 | 100 | 0.142 | 21% |
| Al Muteena – Hor Al Anz | Arterial | 0.98 | 0.41 | 1.05 | 60 | 0.137 | 80% |
| Abu Hail – Hor Al Anz | Arterial | 1.29 | 0.46 | 1.05 | 60 | 0.054 | 80% |
| Hor Al Anz – Al Khabaisi | Expressway | 1.93 | 0.12 | 3.46 | 100 | 0.034 | 21% |
| Hor Al Anz East – Al Wuheida | Arterial | 1.01 | 0.37 | 1.21 | 60 | 0.011 | 80% |
| Hor Al Anz | Arterial | 1.46 | 0.43 | 1.32 | 60 | 0.003 | 80% |


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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| East – Al Mamzar | | | | | | | |

The two communities share seven boundaries with neighbors. To the south, boundaries with Al Khabaisi and Al Twar are expressways, characterized by the lowest permeability and widest crossing spacing. To the north and west, arterial boundaries with Abu Hail and Al Wuheida carry the highest edge betweenness among this set, serving as the pedestrian spine connecting the core to the east. The boundary between the two Hor Al Anz communities is a local street, effectively not a barrier. This table format is suitable for reporting the inventory for every community in the cluster.

### Robustness of the Ranking to Permeability Assumptions

Because the permeabilities are illustrative, the ranking was recomputed 150 times with class-level permeabilities perturbed by 25% noise on each edge. The Spearman correlation between each perturbed ranking and the original paper ranking averaged 0.971 (fifth percentile 0.947). On average,

4.8 of the top five most severed communities remained consistent. This indicates that the ranking is primarily a property of the cluster's topology and barrier classes rather than specific permeability values, making it reliable for reporting before the inventory is finalized.

## Discussion

### Reading the Ranking

The CSPI effectively fulfills the framework's objective: it distinguishes between communities severed by design and those severed by geography. It pinpoints severance along the E11 corridor and the

airport edge. Crucially, it identifies boundaries whose opening would alleviate the most detours for the greatest number of communities. Its most valuable attribute is its interpretable response to interventions. A crossing on a specific boundary alters the permeability of one edge, which modifies effective distances through it, consequently changing the score of every community based on paths utilizing that edge. This detailed accounting is precisely what a road authority requires when deciding on the placement of a footbridge, underpass, or signalized at-grade crossing.

### Hor Al Anz and Its Neighbors

The two Hor Al Anz communities exemplify the broader findings. Internally, they possess some of Dubai's best-connected street networks, as documented by Alawadi, Alameri, and Scoppa (2023). The connectivity challenge lies at their edges. To the south, the expressway separates them from Al Khabaisi and Al Twar—communities with shared labor markets, schools, and clinics. Simulation suggests only one in five short trips across this boundary is walked. To the north and west, arterial boundaries with Abu Hail and Al Wuheida are crossable but involve detours and delays, with the simulation indicating a median detour of 50% and a 20% reduction in walking. The most cost-effective intervention for these communities is not on their internal streets but on the boundary shared with communities across the expressway, where a single, well-placed crossing would benefit both sides.

### Connectivity Equity

The Gini coefficient result is arguably the paper's most policy-relevant finding and the most likely to persist even after illustrative permeabilities are replaced with inventoried data. This is because it relies on the cluster's topology rather than precise values. Expressways are unevenly distributed across the cluster. Communities they bound tend to be newer, larger, and more car-oriented (towards the Sharjah border), while those they spare are older, denser, and more walkable (near the Creek). Severance thus compounds an existing gradient. A program adding crossings where they are cheapest—on arterials—improves the average but widens the gap. Conversely, a program adding crossings where detours are longest—on expressways—narrows the gap. Anciaes et al. (2018) found that pedestrians value grade-separated crossings least, suggesting a preference for at-grade or shallow-ramp designs where permitted by speed limits. They also argue for treating expressway crossings as public spaces rather than mere engineering structures.

### Relation to the Road Program

The Roads and Transport Authority's current program involves adding bridges, tunnels, and lane capacity on corridors bounding these communities. Each such project alters permeability, typically decreasing it at grade and increasing it where a crossing is incorporated. The framework offers a method to make this trade explicit: a project's CSPI effect can be calculated before approval, based on its impact on boundary permeability and the associated cost of any necessary crossings. This approach mirrors the concept of a carbon budget for the same program outlined in a companion paper, applying the principle that the cost of a barrier should be accounted for where it is incurred.


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### From Communities to Streets

The community graph identifies significant boundaries but does not specify where crossings should be located on them. This task falls to a street-level graph analysis, such as that proposed by Porta et al. (2006) and Boeing (2017), on which measures like pedestrian route directness (used by Alawadi et al.) can be computed for potential crossing sites. These two levels integrate naturally: the community graph ranks the boundary, the street graph pinpoints the crossing, and the negative binomial model, once validated with field data, predicts the resulting crossings. Appendix B details the inventory required for all three components to operate with real-world data.

### Health and Social Co-benefits

The framework's outcome layer justifies the investment in crossings. Mindell and Karlsen (2012) outline the pathways from severance to health: reduced walking, fewer social contacts, poorer access to services, and increased exposure to traffic risk when people cross anyway. Higgsmith and colleagues (2022) demonstrate that a severance index based on resident perceptions predicts self-rated health, and Mouratidis (2018) shows that ease of encounter influences social dynamics. For the Deira cluster, where eastern communities house large working populations in shared accommodations with limited car access, the walking restored by an expressway crossing is not recreational; it is essential for commuting to clinics, metro stations, mosques, or parks. A before-and-after study at the pilot boundary should therefore measure walking share and access to these destinations, not solely crossing counts.

### Institutions

Severance falls into an institutional gap. Roads belong to the Roads and Transport Authority, communities to Dubai Municipality, and crossings to whichever entity builds them, while pedestrians belong to neither. Daouda's (2024) finding that coordination, not technology, limits smart-city delivery in the region strongly applies here. The connectivity budget proposed in Recommendation 3 serves as a coordination mechanism: it assigns responsibility to the road authority for permeability removed by its projects and provides the municipality with a metric to monitor. The annually published CSPI becomes a shared measure visible to both institutions.

### What International Practice Suggests

Cities that have seriously addressed severance have taken three actions that Dubai could adopt:

Measured It: Employing tools similar to those triangulated by Mindell and colleagues (2017) in London ensures severance is considered quantitatively in project appraisal, not just asserted.

Valued It: Utilizing stated-preference evidence, like that produced by Anciaes, Jones, and Metcalfe (2018), justifies crossings with the same economic rigor as lane additions.

Treated Crossings as Public Space: Designing at-grade crossings where speed permits and, where it does not, constructing wide, well-lit, shaded, and short bridges and underpasses. The Deira cluster's expressway boundaries are candidates for all three types, and the airport edge, which severs Al Garhoud and Al Twar from northern communities, represents a prime case where the design-only variant of the CSPI would be most insightful.

## Recommendations

**Table 8.** outlines recommendations, ownership, and horizons.

| # | Recommendation | Owner | Horizon | Basis |
|---|---|---|---|---|
| 1 | Complete the barrier and crossing inventory for the Deira cluster (Appendix B): class, crossing spacing, crossing type and signal timing for every shared boundary. | RTA Traffic & Roads Agency;Dubai Municipality GIS | 6 months | Sections4.2,5.4 |
| 2 | Adopt the CSPI as a reported indicator for every community, | DubaiMunicipality planning; RTA | 12 months | Sections3.2,5.1 |


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| | | | | |
|---|---|---|---|---|
| | computed from the inventory and published with the Dubai 2040 neighbourhood indicators. | | | |
| 3 | Attach a connectivity budget to every road project that touches a community boundary: the project must leave the CSPI of adjacent communities no worse, with crossings costed within the scheme. | RTAproject approval | Immediate fornew approvals | Section 6.4 |
| 4 | Prioritise expressway crossings over arterial ones where the objective is equity, and use at-grade or shallow-ramp designs wherever design speed permits. | RTA design; Dubai Police | Programme | Sections5.5,6.3; Anciaes etal. (2018) |
| 5 | Treat the Hor Al Anz – Al Khabaisi – Al Twar expressway boundary as the pilot crossing programme, with before-and-after pedestrian counts. | RTA;Dubai Municipality | 18 months | Section 6.2 |
| 6 | Field the crossing-count model on inventoried segments and use it to forecast demand for candidate crossings before construction. | RTA traffic data; Emirates Scholar Center | After inventory | Section 5.4 |
| 7 | Run the street-level route-directness analysis for candidate locations on the top-ranked boundaries. | Dubai Municipality; academic partner | After inventory | Section 6.5 |

## Conclusions

Community severance represents the cost imposed by a road that people who do not use it must bear. This paper proposes a method for quantifying this cost in Dubai, utilizing the city's own community boundaries, a manageable graph for analysis, an index responsive to interventions, and models connecting boundary design to crossing behavior. Applied to the Deira cluster, the demonstration reveals concentrated severance along the E11 corridor, distributed unevenly in favor of older Creek-side communities. It suggests that a program placing crossings where detours are longest, rather than cheapest,


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can effectively reduce this severance. For Hor Al Anz and its neighbors, the key message is specific: the neighborhood is internally connected but externally severed at its southern edge. A single crossing at this edge would provide greater benefit to residents than any street improvement.

The inventory needed to transition this demonstration to a precise measurement is outlined, forming the paper's primary recommendation.

Data Availability, Acknowledgements and Declarations

The analysis script, community-boundary layer, illustrative segment, trip, and community tables, along with all figures, are available from the corresponding author. The pipeline regenerates every result from an inventoried boundary table using the variable names specified in Table 2. The author acknowledges Dubai Municipality for providing the public community-boundary data. No external funding was received. Generative AI tools assisted with code for figure generation; the design, analysis, and text remain the author's own.

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