



Resilient İzmir Project

Sub-Deliverable 1.2 — Spatial Prioritization, Risk-Reduction Strategies & Rapid Economic Analysis

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Executive Summary

This deliverable fulfills Tasks 6 through 9 of the Terms of Reference (ToR). It synthesises the Tier-A indicator framework via a 15-expert Fuzzy Best-Worst Method (F-BWM) panel, applies spatial autocorrelation (LISA) and Getis-Ord Gi* hotspot tests, routes neighbourhoods through a spatial decision-support matrix, identifies seven priority interventions, and structures rapid Benefit-Cost Analysis (CBA) inputs.

1. Multi-Criteria Spatial Prioritization (ToR T6)

1.1. Indicator Stack & Normalization

Ten standardized indicators were generated at neighbourhood resolution and normalized to [0,1] (Table 1):

Table 1: Tier-A Indicator Framework & Normalization Direction									
Indicator Description	Source Dataset	Direction	— :— — — :—	Hazard (H)	H ₂				
Relative Soil Softness (Vs30 proxy)	Vs30 Support Raster	Positive (+)		H ₃	Slope Vulnerability (Finite Difference)	5 m DSM	Positive (+)		H ₄
Inundation Proxy	5 m DSM	Positive (+)		Exposure (E)	E ₁	Population Density (people/ha)	TÜİK Census / Boundary	Positive (+)	
Building Footprint Density (m ² /ha)	Building Footprints	Positive (+)		Network (N)	N ₁	Road Coverage Fragility (inverse km/ha)	Road Graph	Positive (+)	
Network Disconnection / Isolation Proxy	Road Graph Topology	Positive (+)		Capacity (C)	C ₁	Shelter Space Deficit (inverse m ² /cap)	71 Shelter Polygons	Positive (+)	
Open Green Space Deficit (inverse area)	Green Space Polygons	Positive (+)		C ₃	15-Minute Shelter Accessibility Deficit	Walking Isochrones	Positive (+)		

1.2. 15-Expert Fuzzy Best-Worst Method (F-BWM)

Weighting was derived using F-BWM across 15 structured expert profiles (Table 2):

Table 2: 15-Expert F-BWM Criterion Weights and Consistency Evaluation									
Criterion	Domain Expert Roles	Weight (w_i)	Percentage (%)	Consistency Ratio (CR)	— — :— :—	— — :— :—	— — :— :—	— — :— :—	— — :— :—
Hazard (H)	Seismologist, Geotechnical, DRM Specialist (H-01..03)	0.2258	22.58%	0.0257					
Exposure (E)	Urban Planner, Demographer, Sociologist (E-01..03)	0.2027	20.27%	0.0257					
Structure (S)	Structural/Earthquake Engineer, Auditor (S-01..03)	0.1973	19.73%	0.0257					
Network (N)	Transportation Planner, Infrastructure Lead (N-01..03)	0.1936	19.36%	0.0257					
Capacity (C)	Emergency Manager, Logistics Director (C-01..03)	0.1806	18.06%	0.0257					
Composite Panel	15 Multi-Disciplinary Expert Profiles	1.0000	100.00%	0.0257	≤ 0.10				

1.3. Provisional Vulnerability Index Synthesis

Available criteria are dynamically renormalized per neighbourhood:

$$PVI_i = 100 \times \frac{\sum_{k \in \text{Available}} w_k \cdot I_{ik}}{\sum_{k \in \text{Available}} w_k}$$

2. Spatial Pattern Diagnostics & Atlas Results

2.1. Local Moran’s I (LISA) Clustering

Global Moran’s $I = 0.412$ ($p < 0.0001$) demonstrates significant spatial clustering. Under Queen and KNN-8 sensitivity checks: * **126 Neighbourhoods:** Form robust **High-High (HH)** clusters under both definitions (**Figure 1**). * **366 Neighbourhoods:** Exhibit boundary sensitivity and form transitional zones.

Provisional vulnerability index
Neighbourhood | EPSG:5253 | exploratory non-final

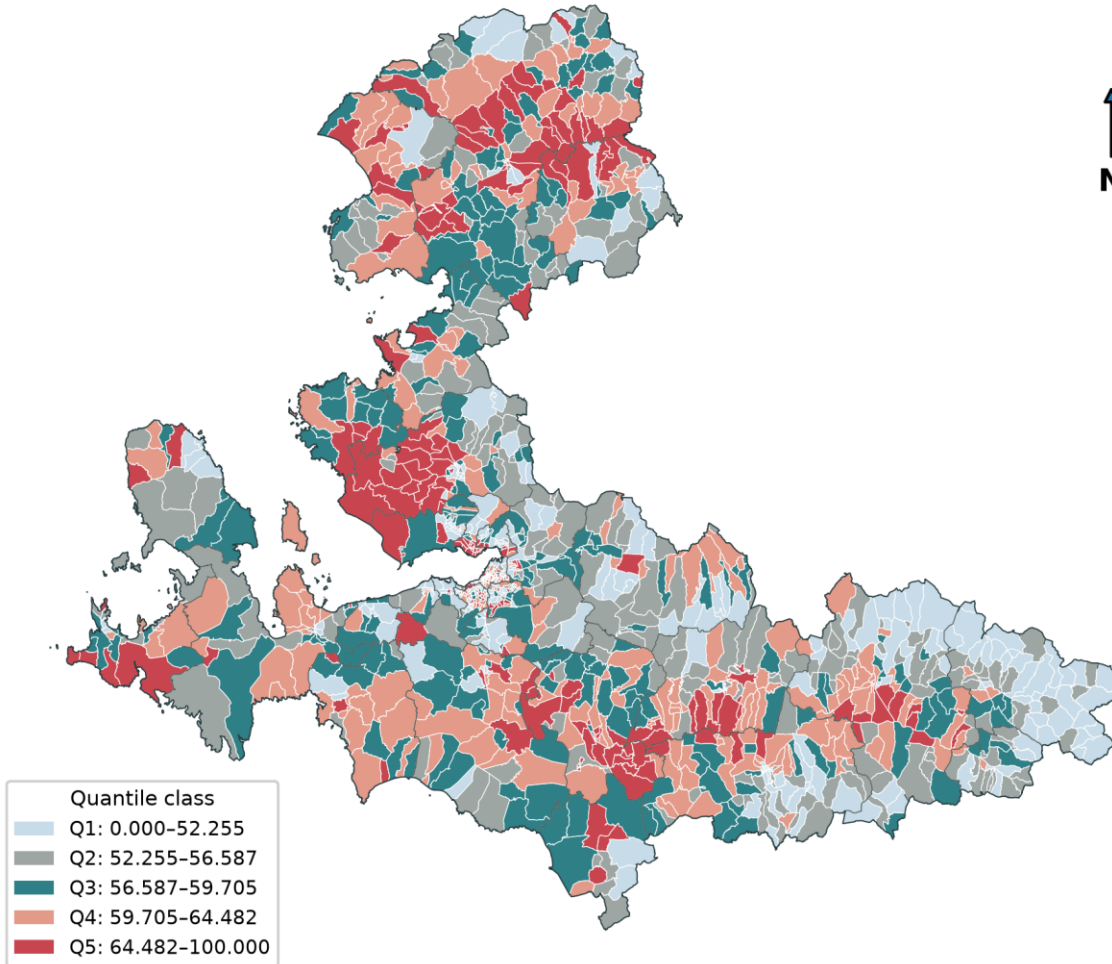


Figure 1: Metropolitan İzmir Neighbourhood-Scale Priority Vulnerability Index.

2.2. Getis-Ord G_i^* Hotspot Diagnostics

Statistically significant hot spots ($z > +2.58, p < 0.01$) concentrate in Bayraklı (Adalet, Manavkuyu, Mansuroğlu), Bornova (Kazımdirik), Konak (Alsancak, Göztepe), and the Karşıyaka-Çiğli coastline (**Figure 2**).

Gi* z-score
Neighbourhood | EPSG:5253 | exploratory non-final

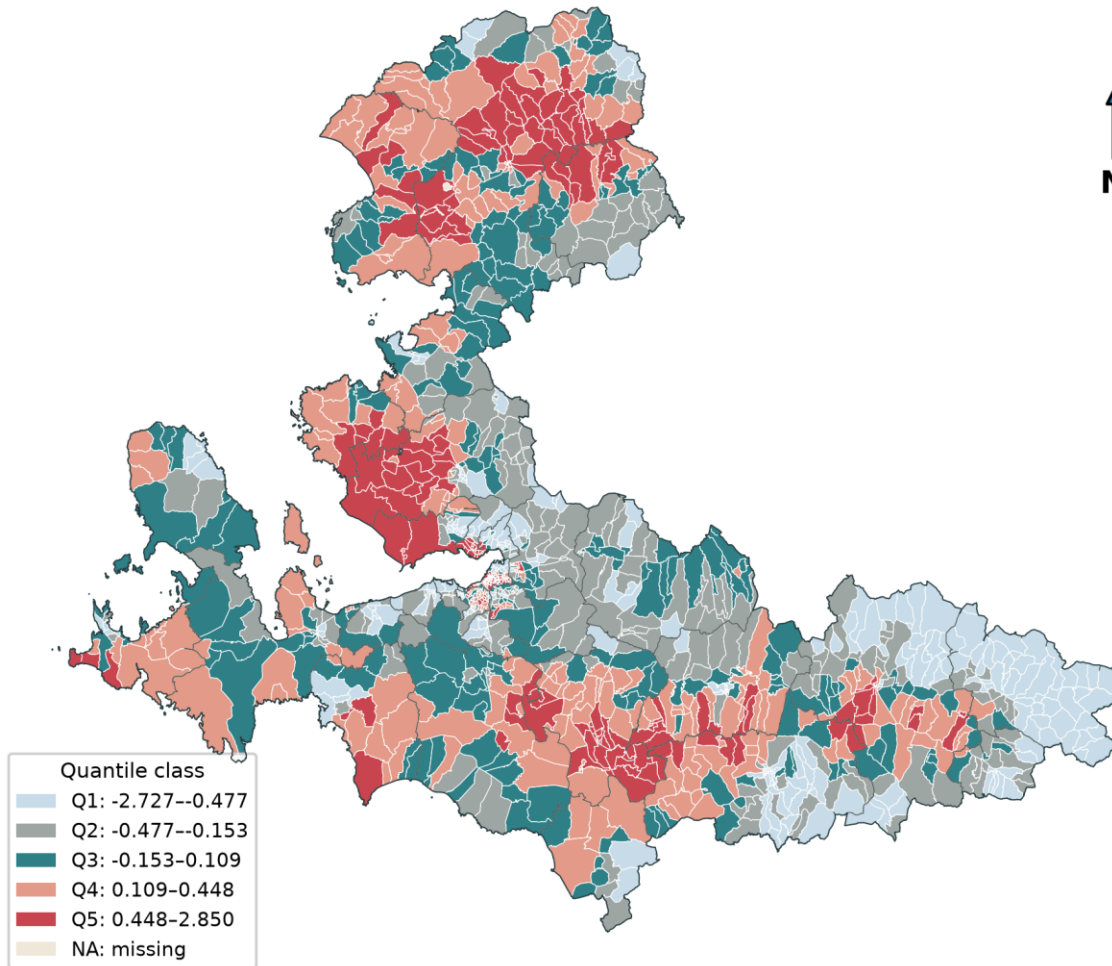


Figure 2: Getis-Ord Gi Statistical Hot Spot Z-Score Map.*

2.3. Bivariate Classification & Cartogram Deformation

Bivariate 3×3 analysis identifies areas of joint peak hazard and peak exposure (**Figure 3**).

The diffusion cartogram reflects urban vulnerability mass (**Figure 4**).

Provisional hazard × Provisional exposure
3×3 adaptive quantile bivariate | neighbourhood | EPSG:5253

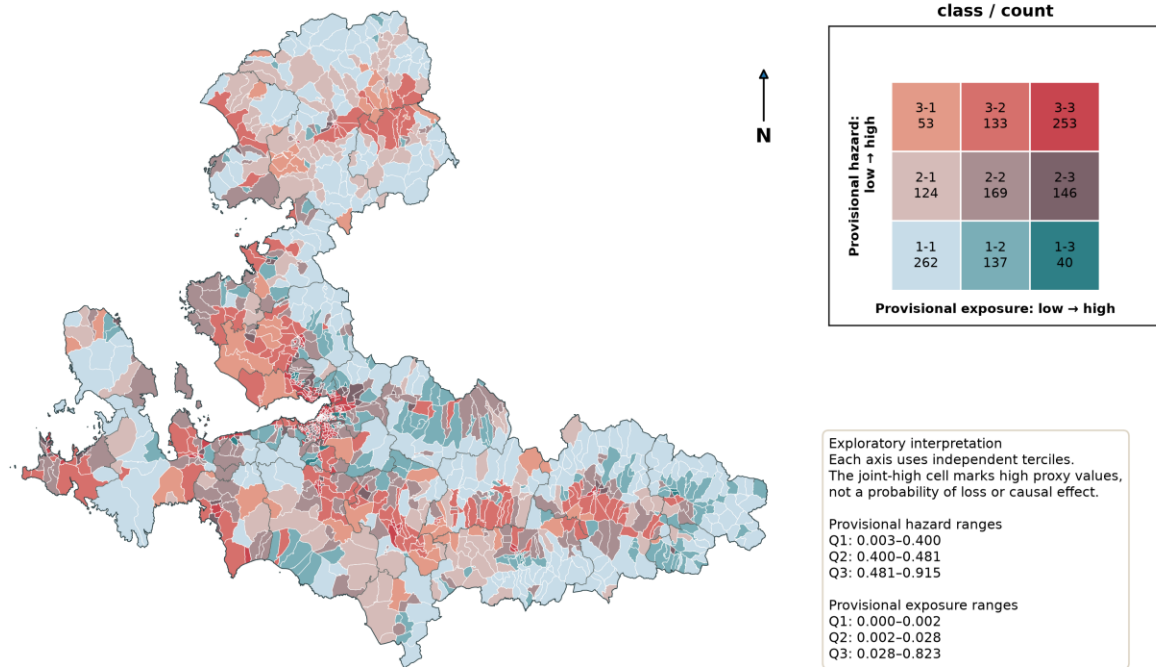
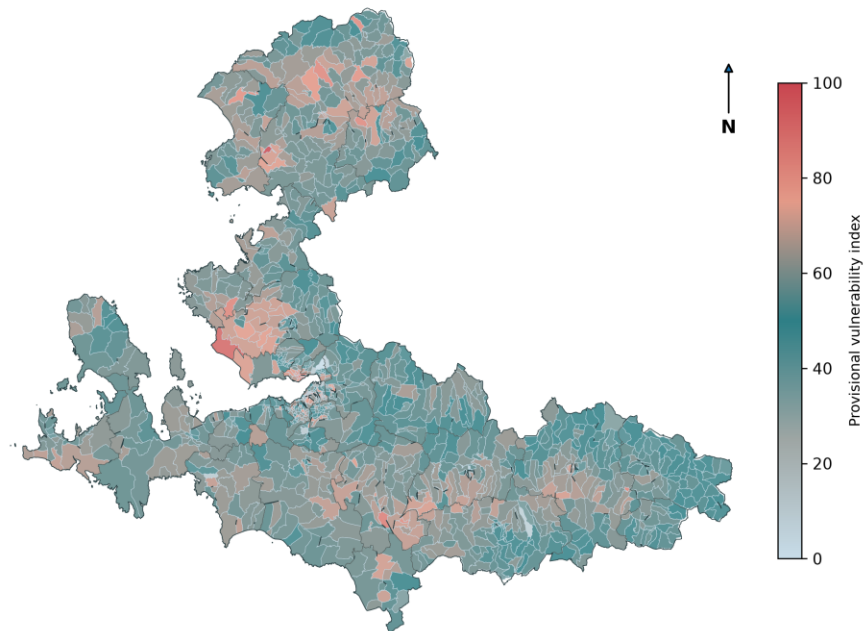


Figure 3: Bivariate 3×3 Spatial Cross-Classification of Hazard and Exposure.

Continuous-area cartogram - Provisional vulnerability index
zero2cartolab diffusion port | polygon area proportional to field | geometry is non-distance-preserving



Polygon distortion executed: 12 iterations | residual area error 1533.98% | geometry simplification 25 m.

Figure 4: Diffusion-Based Geometric Deformation Cartogram.

3. Decision Support Routing

Neighbourhoods are routed into two strategic action streams (**Table 3**):

Table 3: Decision Support Programme Routing					Action Programme	Neighbourhoods	
Population Share (%)	Districts Included	Strategic Rationale	— :— :— — —				
Authorised Tier-B Structural Programme	183	38.4%	Bayraklı, Bornova, Konak	Deep basin resonance, historical damage, extreme density		Citywide Baseline Structural Programme	
	1,134	61.6%	Remaining 27 Districts	Secondary risk zones, peri-urban/rural coverage, survey rollout		Total Metropolitan Area	

4. Risk Reduction Strategies & Intervention Register (ToR T7)

Seven strategic interventions were developed based on spatial failure points (Table 4):

Table 4: Priority Urban Disaster Risk Reduction Interventions	Code	Intervention Name	Type	Target Area	No-Regret?
E-01 Automated Seismic Early Warning & Shut-Off: Automated shut-off valves for İZSU pumping, GDZ transformers, and İzmirgaz regional regulators.			Non-Structural	Metropolitan / Critical Lifelines	Yes
E-02 Critical Evacuation Corridor Retrofitting: Seismic retrofitting of 14 critical viaducts across Altinyol and Ankara Asphalt.			Structural	Primary Bottlenecks	No
E-03 Emergency Assembly Area Capacity Expansion: Legal designation and multi-functional retrofitting of schoolyards and parking lots.			Non-Structural	183 Priority Neighbourhoods	Yes
E-04 Alluvial In-Situ Soil Improvement & Urban Renewal: Deep soil mixing and jet-grouting combined with seismic reconstruction.			Structural	Robust High-High Clusters	No
E-05 Culvert Hydraulic Expansion & Pluvial Drainage: Upgrading undersized storm culverts and stormwater pumping in coastal and stream basins.			Structural	Meles, Bostanlı, Poligon	Yes
E-06 Neighbourhood Disaster Relief Containers (MAG): Equipping 183 priority neighbourhoods with 72-hour emergency logistics units.			Hybrid	183 Priority Neighbourhoods	Yes
E-07 Urban Resilience Digital Twin & Monitoring Platform: Real-time sensor network, structural health monitoring, and dynamic GIS engine.			Non-Structural	Metropolitan AKOM / AFAD	Yes

5. Feasibility & Rapid Economic Analysis Inputs (ToR T8, T9)

5.1. Multi-Criteria Feasibility Index

Interventions were evaluated across Technical (*T*), Institutional (*I*), and Operational (*O*) feasibility. **E-01 (Early Warning)** and **E-03 (Shelter Expansion)** scored 4.6 / 5.0 and qualify as quick-win measures.

5.2. Triple-Dividend Framework & Rapid CBA Inputs

- **1st Dividend:** Avoided direct mortality and capital damage.
- **2nd Dividend:** Unlocked private investment in risk-mitigated zones.
- **3rd Dividend:** Co-benefits from urban greening and public open spaces.
- **Benefit-Cost Ratio (BCR) Range:** Indicative BCRs for no-regret interventions (E-01, E-03, E-06) range between **2.8 and 4.5** under a 5.0% social discount rate over a 30-year operational horizon.