EEFIT REPORT

THE M_W6.2 WESTERN MARMARA SEA EARTHQUAKE OF 23 APRIL 2025

A Preliminary Assessment of Ground Motion, Building Vulnerability, Societal Response and Istanbul's Readiness for the Anticipated Major Event

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Executive Summary

The Mw 6.2 Western Marmara Sea earthquake of 23 April 2025 ruptured the Kumburgaz segment of the Main Marmara Fault at shallow depth, generating peak ground accelerations of up to 0.22 g (NS component of Station 3415, Küçükçekmece) – approximately half of the design code levels at that location. One person died, 359 injuries were recorded across the Marmara region, and 4,295 buildings were classified as slightly damaged in Ministry assessments (Kurum, 2025a). Major lifelines were unaffected. Based on the level of ground shaking and losses, it was classed as a moderate event.

This report argues that the significance of the 2025 event lies not only in its direct physical and societal impacts – which were, in absolute terms, modest – but in what those impacts revealed about Istanbul's preparedness for the substantially larger event that the seismological evidence indicates is pending on the Princes' Islands segment of the Main Marmara Fault. The earthquake ruptured a segment that had accumulated approximately 260 years of tectonic strain and released approximately 8% of it – equivalent to roughly 0.3 m of slip – leaving approximately 3.4 m of accumulated deficit unreleased on the Kumburgaz segment and transferring stress toward the locked Princes' Islands segment south of Istanbul's historic peninsula – the identified source of an anticipated major Marmara earthquake in the future. Aftershock migration tracked eastward toward this locked segment within 24 hours of the mainshock (Eken et al., 2025). Martínez-Garzón et al. (2025) place the 2025 event within a fifteen-year sequence of eastward-migrating moderate ruptures converging on this segment. The 2025 earthquake has not relieved the seismic hazard facing Istanbul; the available evidence indicates it has incrementally increased the probability of a major rupture on the Princes' Islands segment.

Ground motion, structural assessment and tsunami

The 212-station AFAD-TADAS and KOERI strong-motion network produced one of the densest sets of urban ground motion records in the world for a moderate earthquake. Chapter 2 presents a unified analysis of this dataset, including a comparative evaluation of the predictive performance of four established ground motion prediction equations applicable to shallow crustal earthquakes in the Europe and Middle East region – BSSA14, ASB14, KAAH15 and CB14. Overall, the dataset is characterized by high peak ground motion ordinates on the European side of Istanbul and all ground motion parameters typically fall within the median ±2σ range for all evaluated models. Despite this, the median PGA estimations from KAAH15 exhibit consistent underestimation corroborating findings from previous studies. European-side stations recorded systematically higher peak ground accelerations and spectral values than Asian-side stations at comparable epicentral distances. This observation is independently corroborated by the official building damage report geography (80% of reports from European-side districts) and by the 4,302 EMSC crowdsourced felt intensity reports (mean intensity 4.42 on the European side versus 3.97 on the Asian side). The prevalence of soft soil conditions in these districts (predominantly ZC and ZD site classes) is consistent with this pattern, though a formal site amplification analysis lies beyond the scope of this report.

The building stock experienced ground shaking well below the Turkish code design-level loading: recorded ground motions remained below DD-2 design levels at all stations, with ratios of recorded to design PGA ranging from approximately 20% at Avcılar (Station 3428) to approximately 52% at Küçükçekmece (Station 3415). Aydoğdu and İlki (2026) demonstrate that the limited damage observed in vulnerable pre-1999 buildings reflects the short 13-second ground motion duration rather than structural adequacy, and that buildings of this type showing light damage under the 2025 record would not survive a longer-duration record of comparable PGA. Station 3428 (Avcılar) recorded both the largest long-period spectral accelerations and the longest strong motion duration (D5-95 up to 40.68 s) of the four stations analysed in Chapter 5 – a combination consistent with known basin resonance effects in Avcılar and consistent with its anomalously high damage rates in the 1999 earthquakes. ESDOF analyses (Chapter 5) confirm that inelastic demand was already reached in vulnerable RC frame typologies in Küçükçekmece, Bakırköy, Avcılar and Silivri under this sub-design loading. These districts correspond closely to those repeatedly identified as highest-risk in Istanbul scenario loss studies since 2002 – confirming, under real-world moderate loading, a spatial vulnerability pattern that engineering analysis had already predicted.

The earthquake also generated a minor tsunami: a maximum wave height of approximately 6 cm was recorded at Erdek, producing no damage, but confirming that the fault is capable of co-seismic seafloor displacement. Worst-case scenario models (Hébert et al., 2005) estimate waves of 3–4 m at the European coastline under a major rupture. The same European-side districts that recorded the highest ground motion ordinates and damage report concentrations in 2025 face a compounded hazard in the major event.

Engineering systems

Following the 1999 Marmara earthquake, Istanbul made sustained investments in earthquake engineering infrastructure: the Istanbul Earthquake Rapid Response and Early Warning System (IERREWS), the IGDAŞ natural gas automatic shut-off network (IGRAS), and a programme of seismic isolation for critical public buildings, with mandatory requirements for hospitals with capacities exceeding 100 beds enacted in 2013. In the 2025 earthquake, these systems performed largely as intended: IERREWS and IGRAS both triggered correctly, and eight base-isolated hospitals remained fully operational throughout the event and its aftershock sequence. These outcomes represent genuine and measurable returns on the post-1999 investment programme and demonstrate that targeted engineering intervention in critical infrastructure can deliver reliable performance under moderate seismic loading.

Building stock and hidden vulnerabilities

Chapter 3 documents why Istanbul's building stock carries the risk it does, and why that risk cannot be read from the regulatory record alone. Approximately 70% of Istanbul's buildings predate the post-1999 regulatory transition; a substantial proportion of the pre-1975 stock was constructed under codes with no ductility requirements, using low concrete grades, smooth reinforcing bars and inadequate stirrup detailing. Scenario loss studies conducted since 2002 – with fatality estimates ranging from 14,000 to 87,000 depending on scenario and methodology – consistently identify the same seven European-side districts as highest-risk: Fatih, Küçükçekmece, Bağcılar, Bahçelievler, Zeytinburnu, Avcılar and Esenyurt. The 2025 damage report geography confirms this pattern under real moderate loading.

Hidden vulnerabilities compound the regulatory picture. Approximately 317,000 buildings in Istanbul have been retroactively legalised through construction amnesties (*imar barışı*), of which roughly 90,000 are considered at serious collapse risk. The condition of this older stock was made concrete by the 2025 inspections: post-earthquake surveys in Küçükçekmece documented RC columns containing marine shell fragments (*midye kabukları*) – concrete made with unwashed beach sand, porous, weak and entirely non-compliant with basic material standards – in buildings representative of the pre-regulatory era. This deficiency was detected under sub-design loading. Separately, the third-party building inspection system (*yapı denetim*), introduced after 1999 to govern new construction, is structurally compromised by its fee and contracting model – inspection firms are contracted and paid by building owners, with fee structures that incentivise cursory sign-off over rigorous site inspection. That 199 buildings in Avcılar confirmed as moderately damaged in the 1999 earthquakes were still standing and occupied on 23 April 2025 – their legally-mandated remediation deadline having passed in 2020 – illustrates how the governance failures documented in this chapter are current, not historical.

Seismic risk mitigation and urban transformation

Since 2012, Istanbul has been carrying out a large-scale urban transformation programme under Law No. 6306, officially aimed at replacing seismically deficient residential buildings. Chapter 4 examines whether the programme is working as intended. The regulatory framework provides two instruments: TBEC 2018 Chapter 15, a comprehensive performance-based assessment that can identify whether structural intervention could bring a building to adequate seismic performance; and the RBTE-2019, a simplified screening procedure that produces a binary risky/not-risky designation. In practice, the RBTE-2019 designation – which yields a risky outcome for virtually all pre-1999 buildings regardless of actual structural condition – is frequently treated as the basis for demolition decisions without triggering the more rigorous TBEC 2018 assessment that should follow. Only around 10% of designated buildings are structurally strengthened rather than demolished (Kayaalp, 2025).

This bias is not only technically unjustified in many cases – structural intervention is feasible for a significant proportion of the vulnerable stock, at 20–40% of the embodied carbon of full replacement – it is being actively exploited: construction companies have systematically purchased a single apartment in pre-1999 buildings, commissioned a risk assessment confident of the designation outcome, and used the resulting classification to force demolition and secure the reconstruction contract and development rights uplift – a practice known colloquially as *deprem korkutmacılığı* (earthquake scaremongering). The financial incentive structure of Law 6306 subsidises demolish-and-rebuild but not structural intervention, leading to the prioritisation of areas of high land value over areas of highest seismic risk, and generates gentrification that progressively displaces lower-income households toward the urban periphery where seismic risk is concentrated and programme activity lowest.

The 2025 earthquake has not resolved questions about the programme's replacement stock. Whether replacement buildings – built by the same industry, subject to the same inspection regime, and designed to the same codes that produced vulnerable post-1999 stock documented in the 2023 Kahramanmaraş sequence – are genuinely more resilient than the stock they replace remains unresolved. Following the 2025 event, the programme was extended through the *Yarısı Bizden* initiative, with 61,000 slightly damaged units declared eligible for support. At the current rate of programme delivery, the 600,000+ high-risk units across Istanbul will not be substantially reduced before the next moderate event, let alone before the major rupture.

Societal response

An estimated 100,000 people spent at least one night outdoors following the earthquake despite the absence of structural collapse in inhabited buildings. Intercity coach fares tripled within hours. Rental prices in stable-ground districts rose over 100% within the first day. The Fear of Earthquake Scale (FES) data collected by EMSC in near-real time – 186 respondents, mean score 22.60/35, 42% in the high-fear range – indicate elevated seismic fear levels consistent with a population carrying the accumulated psychological weight of decades of seismic risk awareness, amplified by the direct experience of the 2023 Kahramanmaraş sequence. This is the first application of the FES to a real-time post-earthquake dataset. Outdoor sheltering was spatially sorted: European-side residents were significantly more likely to remain outdoors than Asian-side residents, consistent with rational risk assessment of their buildings' structural quality. The FES data, together with the behavioural evidence, indicate that the scale of the societal response reflects not disproportionate panic but a calibrated population response to a widely recognised existential risk – a distinction with direct implications for emergency planning assumptions about behaviour in the major event.

Institutional performance

Four institutional frameworks nominally designed to protect Istanbul's population against earthquake were tested at moderate scale and found deficient – in each case replicating failures documented after previous events without substantive reform.

The DASK compulsory earthquake insurance system paid out as little as 6,400 TL for multi-room damage. The deductible and coverage ceiling structures render the instrument near-ineffective for the light-damage category produced by moderate events. This is not a new finding: the same structural inadequacy was documented after the Elazığ (2020), İzmir (2020) and Düzce (2022) earthquakes without reform. In the 2023 Kahramanmaraş sequence, DASK paid approximately 147,000 TL for a completely destroyed dwelling and then sought to claw back 75,000 TL of that amount – illustrating the consequences of the same coverage structure at catastrophe scale.

The housing market sorted by perceived seismic safety within hours, with stable-ground district prices rising over 100%. This accelerates the progressive concentration of lower-income households in the highest-risk districts, compounding physical and social vulnerability in the same spatial pattern that scenario loss studies have documented since 2002.

The assembly area system failed operationally: Formally designated areas were blocked, encroached by construction sites, or simply absent. The average per-capita assembly area provision across Istanbul of 2.98 m² falls below the Sphere Project minimum of 3.5 m², and 419 of 496 post-1999 designated areas have been converted to commercial development. These failures were not caused by the earthquake: locked gates, construction encroachment and prior commercial conversion are pre-existing, knowable conditions that an operational audit would have identified.

Mobile telecommunications saturation – network congestion preventing voice and SMS communication within minutes of the mainshock across European-side districts – has been documented after every significant Turkish earthquake since 1999 and remains unaddressed 26 years later. Official communication also failed: the Education Minister's statement on 23 April that "none of our schools have any issues" was followed within a week by the announcement that four schools had been evacuated on structural grounds.

Compound spatial vulnerability

The districts generating the highest building damage report concentrations in 2025 – Bahçelievler, Esenler, Bağcılar, Zeytinburnu, Avcılar, Esenyurt – are also those with the lowest per-capita assembly area provision, the highest proportions of pre-1999 RC building stock on soft alluvial ground, the highest rates of lower-income household concentration following seismic-risk-driven outmigration, the lowest urban transformation programme uptake, and – critically – the populations with the fewest resources to absorb uninsured repair costs when DASK fails them. This co-location reflects sixty years of urbanisation dynamics, regulatory non-enforcement, construction amnesties and housing market responses to seismic risk. It is not coincidental, and it will determine the spatial distribution of casualties and displacement in the major event.

The preparedness gap

The failures documented in this report are regulatory in nature. Assembly area legal protection and operational audit, DASK deductible and coverage reform, urban transformation programme reorientation directed toward the highest-risk districts, telecommunications resilience standards, and building inspection enforcement are all within the existing competence of the relevant authorities. They have been available as policy options since 1999. Their persistence across successive moderate events – Elazığ in 2020, İzmir in 2020, Düzce in 2022, Marmara in 2025 – without substantive resolution is a matter of record. This report provides a specific, documented and dated account of what was known and what remained unaddressed as of May 2026. The eight key messages below summarise the principal findings.

Key Messages

KM1. The 2025 rupture did not reduce the probability of a major event on the Princes' Islands segment – it incrementally increased it. The Kumburgaz segment released approximately 8% of accumulated strain since 1766, transferring stress toward the locked Princes' Islands segment south of Istanbul. Aftershock migration tracked eastward toward this segment within 24 hours of the mainshock. Probabilistic estimates place the likelihood of a Mw≥7 rupture on the Princes' Islands segment at 35–70% over the coming decades. The scientific evidence indicates the 2025 event has incrementally increased rather than relieved this hazard.

KM2. The building stock in the most affected European-side districts was not substantively tested, and the 2025 result does not validate it for the anticipated major event. Recorded ground motions remained well below DD-2 design levels, ranging from approximately 20% of design PGA in Avcılar to approximately 52% in Küçükçekmece. Aydoğdu and İlki (2026) demonstrate that limited damage reflects the short 13-second ground motion duration, not structural adequacy. ESDOF analyses confirm inelastic demand was already reached in vulnerable typologies in the highest-risk European-side districts at sub-design loading – so while the stock as a whole was not substantively tested, its most vulnerable segment was already responding inelastically. Avcılar recorded both the highest inelastic demand exceedance rates and the longest strong motion duration (D5-95 up to 40.68 s) – a combination pointing to compounded structural vulnerability that a longer-duration major event will fully expose. The earthquake also generated a minor tsunami (6 cm maximum observed), confirming co-seismic seafloor displacement; worst-case scenario modelling estimates 3–4 m waves at the European coastline under a major rupture.

KM3. Istanbul's building stock carries hidden vulnerabilities that extend well beyond the pre-1999 regulatory record, and the 2025 earthquake made them visible. Approximately 317,000 buildings have been retroactively legalised through construction amnesties, of which roughly 90,000 are considered at serious collapse risk. The third-party building inspection system (*yapı denetim*) is structurally compromised by its contracting model, which incentivises cursory sign-off over rigorous site inspection. Post-earthquake inspections in Küçükçekmece in 2025 documented RC columns containing marine shell fragments – concrete made with unwashed beach sand, indicating fundamental material quality failure detectable under sub-design loading. Buildings moderately damaged in the 1999 earthquakes and never demolished or remediated were still occupied on 23 April 2025. These are not historical deficiencies: they are present and observable in the current stock.

KM4. Istanbul's urban transformation programme is not consistently targeting the right buildings, using the right methods, or directing resources toward the highest-risk districts. Only around 10% of designated buildings are structurally strengthened rather than demolished, despite intervention being technically feasible and substantially less carbon-intensive for a significant share of the stock. The programme's financial incentive structure has been systematically exploited: construction companies purchase a single apartment in a pre-1999 building, commission a risk assessment confident of the outcome, and use the designation to force demolition and secure the reconstruction contract and development rights uplift – a practice the chapter documents as *deprem korkutmacılığı* (earthquake scaremongering). The programme prioritises high-value over high-risk districts, and generates gentrification that progressively displaces lower-income households toward the most seismically vulnerable areas. At current delivery rates, the 600,000+ high-risk units across Istanbul will not be substantially reduced before the next moderate event. Whether replacement buildings are genuinely more resilient than the stock they replace – or replicate the same construction quality failures in a modern configuration – remains unresolved.

KM5. The scale of Istanbul's societal response to a one-fatality earthquake reflects a chronically elevated seismic fear baseline and rational risk assessment, not disproportionate panic. An estimated 100,000 people spent at least one night outdoors; intercity coach fares tripled; rental prices in stable-ground districts rose over 100% within hours; 950,000 people left Istanbul for other provinces in 2023 and 2024. FES data collected in near-real time by EMSC – mean score 22.60/35, 42% of respondents in the high-fear range – indicate fear levels consistent with a population carrying decades of accumulated seismic risk awareness, compounded by the direct experience of the 2023 Kahramanmaraş sequence. This is the first application of the FES to real-time post-earthquake data. Outdoor sheltering was spatially sorted by perceived building vulnerability: the same European-side districts with older, more vulnerable stock saw higher rates of residents refusing to re-enter their buildings. This is not irrational behaviour; it is a calibrated population response to a widely recognised existential risk, and emergency planning models must account for it.

KM6. Four institutional frameworks nominally designed to protect Istanbul's population were tested at moderate scale and found deficient, replicating failures documented after previous events without substantive reform. The assembly area system failed operationally under the most favourable possible activation conditions: formally designated areas were blocked by police, occupied by construction, or absent. DASK provided near-zero meaningful protection for the damage category the event produced; in the 2023 Kahramanmaraş sequence the same instrument paid approximately 147,000 TL for a completely destroyed dwelling, then sought to claw back 75,000 TL. The housing market accelerated the concentration of vulnerable populations in the highest-risk districts. Mobile telecommunications saturation prevented voice and SMS communication within minutes of the mainshock – a failure documented after every significant Turkish earthquake since 1999 and still unaddressed. Official communication also failed: a ministerial assurance that no schools were damaged was contradicted within one week by the evacuation of four schools on structural grounds.

KM7. The physical, social and institutional dimensions of Istanbul's seismic risk are co-located and mutually reinforcing. The districts with the most vulnerable building stock, the least assembly area provision, the highest concentrations of lower-income households, the lowest urban transformation programme uptake, and the populations least able to absorb uninsured repair costs are the same districts. This is not coincidental: seismic risk awareness has driven outmigration of higher-income households toward perceived lower-risk areas, while housing market dynamics and the transformation programme's gentrification effect have progressively concentrated lower-income households in the highest-risk European-side districts. Those least able to absorb the consequences of a major earthquake are being concentrated in the places where those consequences will be most severe.

KM8. The failures documented in this report are amenable to policy intervention without new engineering knowledge or new institutional architecture. Assembly area legal protection and operational audit, DASK deductible structure and coverage ceiling reform, urban transformation programme reorientation toward the highest-risk districts with retrofit subsidies equivalent to demolition subsidies, mandatory telecommunications resilience standards, and building inspection enforcement capable of identifying the construction defects the 2025 event made visible in Küçükçekmece – all are within the existing competence of the relevant authorities. They have been available as policy options since 1999 and have persisted unaddressed through four successive moderate Turkish earthquakes: Elazığ in 2020, İzmir in 2020, Düzce in 2022 and Marmara in 2025.

Özet

23 Nisan 2025 tarihinde meydana gelen Mw 6,2 Batı Marmara Denizi depremi, Ana Marmara Fayı'nın Kumburgaz segmentini sığ derinlikte kırarak harekete geçirmiş; en yüksek tepe yer ivmesi değeri olarak yaklaşık 0,22 g olarak kaydedilmiştir (İstasyon 3415, Küçükçekmece, K-G bileşeni) – bu değer söz konusu konumdaki tasarım kodu düzeyinin yaklaşık yarısına karşılık gelmektedir. Depremde bir kişi hayatını kaybetmiş, Marmara bölgesinde toplam 359 kişi yaralanmış ve yaklaşık 4.295 binada düşük seviyede hasar meydana gelmiştir. Başlıca altyapı sistemleri işlevselliğini korumuştur. Kaydedilen yer sarsıntısı ve kayıplara dayanarak, bu olay orta büyüklükte bir deprem olarak sınıflandırılabilir.

Bu rapor, 2025 olayının öneminin yalnızca mütevazı doğrudan fiziksel ve toplumsal etkileriyle değil, bu etkilerin Ana Marmara Fayı'nın Prens Adaları segmentinde beklenen çok daha büyük olay karşısında İstanbul'un hazırlık düzeyi hakkında neler ortaya koyduğuyla da değerlendirilmesi gerektiğini savunmaktadır. Deprem, yaklaşık 260 yıllık tektonik gerilim biriktirmiş olan Kumburgaz segmentini kırarak bu gerilimin yaklaşık %8'ini serbest bırakmıştır – bu, yaklaşık 0,3 m'lik atıma karşılık gelmekte olup yaklaşık 3,4 m'lik birikimli açığı Kumburgaz segmentinde kilitli bırakmış ve gerilimi İstanbul'un tarihi yarımadasının güneyindeki Prens Adaları segmentine – gelecekte beklenen büyük bir Marmara depreminin tanımlanmış kaynağına – doğru aktarmıştır. Ana şoktan sonraki ilk 24 saat içinde gerceklesen artçı sarsıntı dizisi, doğuya, bu kilitli segmente doğru, hareket etmiştir (Eken ve diğ., 2025). Martínez-Garzón ve diğ. (2025), 2025 olayını on beş yıllık bir süredir doğuya doğru hareket ederek bu segmente yakınsayan orta büyüklükteki kırılmalar dizisi içinde konumlandırmaktadır. 2025 depremi İstanbul'un maruz kaldığı sismik tehlikeyi azaltmamıştır; mevcut kanıtlar, bu olayın Prens Adaları segmentinde büyük bir kırılma olasılığını kademeli olarak artırdığına işaret etmektedir.

Yer Hareketi, Yapısal Değerlendirme ve Tsunami

212 istasyonlu AFAD-TADAS ve KOERI kuvvetli yer hareketi ağı, orta büyüklükteki bir deprem için dünyada kaydedilen en yoğun kentsel yer hareketi kayıtlarından birini üretmiştir. Bölüm 2, bu veri setinin bir analizi ile, Avrupa ve Orta Doğu bölgesindeki sığ depremlere uygulanabilir ve yaygın kabul gören dört yer hareketi tahmin denkleminin (BSSA14, ASB14, KAAH15 ve CB14) performanslarına ilişkin bir karşılaştırmalı değerlendirmesini sunmaktadır. Bu veri seti, genel olarak İstanbul'un Avrupa yakasında yüksek tepe yer hareketi değerleriyle karakterize edilmekte olup, tüm yer hareketi parametreleri değerlendirilen modellerin genelinde medyan $\pm 2\sigma$ aralığı içinde kalmaktadır. Bununla birlikte, KAAH15 modelinin medyan TYİ tahminleri, önceki çalışmaların bulgularını doğrular nitelikte, sistematik olarak olması gerekenden düşük olma eğilimi sergilemektedir. Avrupa yakası istasyonları, deperm merkez üssüne benzer uzaklıktaki Anadolu yakası istasyonlarına kıyasla sistematik olarak daha yüksek tepe yer ivmesi ve spektral ivme değerleri kaydetmiştir. Bu gözlem; %80'i Avrupa yakasından gelen resmi hasar bildirimleri ve 4.302 adet EMSC tarafından kitle kaynaklı olarak toplanan ve Avrupa yakası icin ortalama 4,42 iken Anadolu yakasında 3,97 olan hissedilen şiddet bildirimi ile bağımsız biçimde doğrulanmaktadır. Bu ilçelerdeki yaygın yumuşak zemin koşulları (ağırlıklı olarak ZC ve ZD sınıfı) bu örüntüyle tutarlı olmakla birlikte, kapsamlı bir saha amplifikasyonu analizi bu raporun kapsamı dışında kalmaktadır.

Etkilenen bölgedeki bina stoğunun maruz kaldığı yer sarsıntısı, Türk deprem yönetmeliği tasarım düzeyinin belirgin biçimde altında kalmıştır: kaydedilen yer hareketleri tüm istasyonlarda DD-2 tasarım düzeyinin altında seyretmiş; kayıtlı ile tasarım tepe yer ivmesi oranları yaklaşık %20 (Avcılar, İstasyon 3428) ile yaklaşık %52 (Küçükçekmece, İstasyon 3415) arasında değişmiştir. Aydoğdu ve İlki (2026), kırılgan 1999 öncesi binalarda gözlemlenen sınırlı hasarın yapısal yeterlilikten değil, kısa 13 saniyelik yer hareketinden kaynaklandığını ortaya koymuş; 2025 kaydı altında hafif hasar gören yapıların benzer tepe yer ivmesine sahip daha uzun süreli bir kayıt altında ayakta kalamayacağını göstermiştir. İstasyon 3428 (Avcılar), Bölüm 5'te analiz edilen dört istasyon arasında hem en büyük uzun-

periyot spektral ivme değerlerini hem de en uzun kuvvetli yer hareketi süresini (40,68 s'ye kadar D5-95) kaydetmiş olup, bu durum bilinen havza rezonans etkileriyle ve söz konusu ilçenin 1999 depremlerindeki anormal yüksek hasar oranlarıyla uyumludur. Eşdeğer TDOF analizleri (Bölüm 5), tasarım düzeyi altındaki yüklemede Küçükçekmece, Bakırköy, Avcılar ve Silivri'deki kırılgan betonarme çerçeve tiplerindeki deperm talebinin halihazırda elastik ötesi seviyeye ulastığını doğrulamaktadır. Bu ilçeler, 2002'den bu yana gerçekleştirilen İstanbul hasar senaryosu çalışmalarında sürekli olarak en yüksek riskli alanlar olarak tanımlanan ilçelerle büyük ölçüde örtüşmekte; böylece mühendislik analizinin daha önce öngördüğü mekânsal kırılganlık örüntüsü, gerçek orta ölçekli yükleme koşullarında teyit edilmektedir.

Deprem aynı zamanda küçük bir tsunami üretmiştir: Erdek'te yaklaşık 6 cm'lik maksimum dalga yüksekliği kaydedilmiş, herhangi bir hasar oluşmamış; ancak bu durum deniz tabanında fayın depremle eşzamanlı yer değiştirmesi üretebileceğini doğrulamıştır. En kötü durum senaryo modelleri (Hébert ve diğ., 2005), büyük bir kırılmada Avrupa kıyılarında 3-4 m'ye ulaşan dalgalar öngörmektedir. 2025'te en yüksek yer hareketi değerleri ve hasar raporu yoğunluğunu kaydeden Avrupa yakası ilçeleri, beklenen büyük olayda bileşik bir tehlikeyle karşı karşıya kalacaktır.

Mühendislik Sistemleri

1999 Marmara depremi sonrasında İstanbul, deprem mühendisliği altyapısına, İstanbul Deprem Hızlı Müdahale ve Erken Uyarı Sistemi (IERREWS), IGDAŞ doğalgaz otomatik kesme ağı (IGRAS) ve 100'ün üzerinde yatak kapasitesine sahip hastaneler için 2013 yılında zorunlu hâle getirilen gereklilikler dahil olmak üzere kritik kamu yapıları için deprem yalıtım programını da içeren sürekli yatırımlar gerçekleştirmiştir. 2025 depreminde bu sistemler büyük ölçüde tasarlandığı şekilde işlev görmüştür: IERREWS ve IGRAS doğru biçimde devreye girmiş; sismik yalıtımlı sekiz hastane, olay boyunca ve artçı sarsıntı dizisi süresince tam kapasitede hizmet vermeye devam etmiştir. Bu sonuçlar gerçek ve ölçülebilir kazanımları yansıtmakta; kritik altyapıya yönelik hedefli mühendislik müdahalelerinin orta düzey sismik yüklemede güvenilir performans sağlayabildiğini ortaya koymaktadır.

Bina Stoğu ve Gizli Kırılganlıklar

Bölüm 3, İstanbul'un bina stoğunun taşıdığı riskleri ve bunların altında yatan sebepleri ele almakta, ve bu riskin yalnızca mevzuat kaydından okunamayacağını belgelemektedir. İstanbul binalarının yaklaşık %70'i 1999 sonrası geçiş döneminden önceye tarihlendirilmektedir; özellikle 1975 öncesi stoğun önemli bir bölümü, sünek olmayan tasarım gereklilikleri, düşük beton dayanımları, düz donatı çubukları ve yetersiz etriye ayrıntılandırmasıyla mevzuat öncesi kodlar kapsamında inşa edilmiştir. 2002'den bu yana gerçekleştirilen senaryo hasar çalışmaları metodolojik detaylara bağlı olarak 14.000 ile 87.000 arasında değişen ölü tahminlerine işaret etmekte ve aynı yedi Avrupa yakası ilçeyi sürekli olarak en yüksek riskli alanlar olarak tanımlamaktadır: Fatih, Küçükçekmece, Bağcılar, Bahçelievler, Zeytinburnu, Avcılar ve Esenyurt. 2025 hasar bildirileri, bu örüntüyü gerçek orta büyüklükteki yükleme koşullarında doğrulamaktadır.

Gizli kırılganlıklar, mevzuat tablosunu daha da karmaşık bir hâle getirmektedir. İstanbul'da yaklaşık 317.000 bina imar affı yoluyla geriye dönük olarak yasallaştırılmış olup bunların yaklaşık 90.000'inin büyük bir depremde ciddi çökme riski taşıdığı düşünülmektedir. Bu eski yapı stoğunun içinde bulunduğu durum, 2025 depremi sonrası incelemelerle somut biçimde ortaya konmuştur: Küçükçekmece'de gerçekleştirilen tespitler, mevzuat öncesi dönemi temsil eden binalarda deniz kabuğu parçaları içeren — yani yıkanmamış deniz kumu kullanılarak üretilmiş, gözenekli, zayıf ve temel malzeme standartlarını karşılamayan betondan mamul — betonarme kolonları belgelemiştir. Bu kusur, tasarım düzeyi altındaki yükleme koşullarında tespit edilmiştir. Yeni yapı üretimine yönelik 1999 sonrasında uygulamaya konan üçüncü taraf bina denetim sistemi ise denetim firmalarının bina sahipleri tarafından sözleşmeyle görevlendirilip ücretlendirilmesi üzerinden kurgulanmakta ve titiz saha denetimi yerine kâğıt üzerinde onay vermeyi teşvik eden bir ücret modeliyle yapısal olarak zayıf kalmaktadır. 1999 depremlerinde Avcılar'da orta hasarlı olarak tescil edilen 199 binanın yasal takviye süreleri

2020 yılında dolmuş olmasına rağmen 23 Nisan 2025 itibarıyla hâlâ kullanımda olduğunun belgelenmesi, yönetişim problemlerinin güncel nitelikte olduğunu ortaya koymaktadır.

Deprem Riski Azaltma ve Kentsel Dönüşüm

İstanbul'da, 2012'den bu yana 6306 sayılı Kanun kapsamında resmi olarak deprem riskine dayanımı yetersiz konut binalarını yenilemeyi amaçlayan büyük ölçekli bir kentsel dönüşüm programı yürütülmektedir. Bölüm 4, programın amaçlandığı gibi işleyip işlemediğini incelemektedir. Bu programa dair mevzuat çerçevesi iki araç sunmaktadır: bir binanın yeterli sismik performansa kavuşturulup kavuşturulamayacağını belirleyen performansa dayalı kapsamlı bir değerlendirme yöntemi olan TBEC 2018 Bölüm 15 ile performans düzeylerini nitelendirmeksizin, ikili olarak riskli/risksiz sınıflandırması üreten basitleştirilmiş bir tarama prosedürü olan RBTE-2019. Uygulamada, 1999 öncesi binaların neredeyse tamamını fiili yapısal durumlarından bağımsız olarak riskli bulan RBTE-2019 tespiti, devamında daha kapsamlı TBEC 2018 değerlendirmesini tetiklemeksizin çoğunlukla yıkım kararlarının dayanağı olarak kullanılmaktadır. Belirlenen yapıların yalnızca yaklaşık %10'u yıkılmak yerine yapısal güçlendirme yoluyla yeterli performans düzeyine kavuşturulmaktadır (Kayaalp, 2025).

Bu eğilim teknik açıdan pek çok durumda temelsiz olmakla kalmamakta; aynı zamanda sistematik biçimde istismar edilmektedir. Yapısal müdahale, kırılgan stoğun önemli bir bölümü için teknik olarak uygulanabilir bir seçenek olup tam yenilemenin gömülü karbon maliyetinin yalnızca %20-40'ına karşılık gelse de, inşaat şirketleri, 1999 öncesi binalarda tek bir daire satın alarak risk tespiti başvurusunda bulunmakta, varolan mevzuat dahilinde kaçınılmaz olan riskli tespitini yıkımı dayatmak ve yeniden yapım sözleşmesi ile yeni binadan daire hakkını güvence altına almak için kullanmaktadır – bu uygulama *deprem korkutmacılığı* olarak bilinen ve belgelenen bir örüntüdür. 6306 sayılı Kanun'un finansal teşvik yapısı yıkıp yeniden yapımı maddi olarak da desteklerken, güçlendirme müdahalelerine herhangi bir destek sağlanmamakta; böylelikle programın kaynakları yüksek riskli ilçeler yerine yüksek arazi değerine sahip bölgelere yönlenmekte ve kentsel dönüşüm, düşük gelirli haneleri giderek sismik riskin yoğunlaştığı kentsel çeperlere baskılayan bir soylulaştırma sürecini beraberinde getirmektedir.

2025 depremi, bu kentsel dönüşüm programı aracılığıyla üretilmis yeni bina stoğunun yeterliği konusunda bir fikir vermemektedir: aynı sektör tarafından, aynı denetim rejimine tabi olarak ve 2023 Kahramanmaraş dizisinde belgelenen 1999 sonrası kırılgan stoğu üreten aynı kodlar kapsamında inşa edilen yenileme binalarının gerçekten daha dayanıklı olup olmadığı tartışmalı olmaya devam etmektedir. 2025 olayının ardından program, Yarısı Bizden girişimi kapsamında genişletilmiş; hafif hasar gören 61.000 birim desteğe basvurmaya uygun ilan edilmiştir. Mevcut teslim hızında, İstanbul genelinde sayısı 600.000'i aşan yüksek riskli konut biriminin, beklenen büyük depremin de ötesinde, bir sonraki orta büyüklükteki olaydan önce bile kayda değer ölçüde güvenli hale getirilmesi mümkün görünmemektedir.

Toplumsal Tepki

İskân edilen binalarda hiçbir yapısal çöküş yaşanmamasına karşın tahminen 100.000 kişi 2025 depreminin ardından en az bir geceyi açık alanda geçirmiştir. Şehirlerarası otobüs bilet fiyatları saatler içinde üç katına çıkmış, sağlam zemin ilçelerindeki kira fiyatları ilk gün içinde %100'ün üzerinde artış göstermiştir. EMSC tarafından ana şokun hemen ardından gerçek zamanlı olarak toplanan Deprem Korku Ölçeği (DKÖ; Sarı ve diğ., 2023) verileri – 186 katılımcı, ortalama puan 22,60/35, %42'si yüksek korku kategorisinde – onlarca yıllık birikimli sismik risk farkındalığının psikolojik ağırlığını taşıyan ve 2023 Kahramanmaraş dizisinin deneyimiyle daha da örselenen İstanbullularda kronik olarak yüksek bir deprem korkusu bulunduğuna işaret etmektedir. Bu, DKÖ'nün bir depremin hemen ardından, saat bazında toplanan gerçek zamanlı verilere ilk kez uygulanmasıdır. Açık alanda barınma, bina güvenliğine dair algıya göre, ve binaların yapısal kalitesine ilişkin rasyonel bir risk değerlendirmesiyle tutarlı biçimde, Avrupa yakası sakinleri tarafından, Anadolu yakası sakinlerine kıyasla çok daha yüksek oranda tercih edilmistir. DKÖ verileri ve davranışsal kanıtlar birlikte değerlendirildiğinde, toplumsal tepkinin ölçeğinin orantısız bir paniği değil;

geniş çaplı biçimde tanınan varoluşsal bir riske kalibre edilmiş bir nüfus tepkisini yansıttığı görülmektedir. Bu ayrım, gelecekte olabilecek bir büyük İstanbul depreminde beklenmesi gereken davranışı açıklaması ve acil durum planlaması varsayımları açısından belirleyici öneme sahiptir.

Kurumsal Performans

İstanbul nüfusunu depreme karşı korumak amacıyla tasarlanmış dört kurumsal çerçeve, 2025 Marmara depreminde orta ölçekte test edilmiş ve yetersiz kalmıştır; her birinde, daha önceki olayların ardından belgelenen başarısızlıklar yinelenmiştir.

DASK zorunlu deprem sigortası sisteminin, birden fazla odasında hasar görülen meskenlere yalnızca 6.400 TL ödeme yaptığı görülmüştür. Tenzil muafiyeti ve teminat tavan miktarları, deperm sigortasını orta büyüklükteki depremlerin ürettiği hafif hasar kategorisi için neredeyse işlevsiz kılmaktadır. Bu, yeni bir tespit değildir: aynı yapısal yetersizlik Elazığ (2020), İzmir (2020) ve Düzce (2022) depremlerinin ardından da belgelenmiş, ancak kayda değer bir reform gerçekleştirilmemiştir. 2023 Kahramanmaraş dizisinde ise aynı sistem, tamamen yıkılan bir konut için yaklaşık 147.000 TL ödeme yapmış ve ardından bu miktarın 75.000 TL'sini geri talep etmiştir; bu durum, aynı kapsam yapısının tam ölçekli bir afette ne gibi sonuçlar doğurabileceğini somutlaştırmaktadır.

Konut piyasası, sağlam zemin bölgelerindeki fiyatlar saatler içinde %100'ün üzerinde artarak sismik güvenlik algısına göre ayrışmıştır. Bu durum, kırılgan nüfusun en yüksek riskli ilçelerdeki en savunmasız konut stoğunda yoğunlaşması sürecini hızlandırmaktadır.

Toplanma alanı sisteminin ise işlevsel olarak başarısız olduğunu görüyoruz: Resmi olarak belirlenmiş alanlar polisçe erişime kapatılmış, şantiyeler tarafından işgal edilmiş ya da hiç mevcut olmamıştır. İstanbul genelinde kişi başına düşen ortalama toplanma alanı büyüklüğü olan 2,98 m², Sphere Projesi'nin önerdiği 3,5 m² asgari eşiğin altında kalmaktadır; 1999 sonrasında belirlenmiş 496 alanın 419'u ticari amaçlı kullanıma açılmıştır. Bu başarısızlıklar depremin yarattığı koşulların ürünü değildir: kilitli kapılar, şantiye işgalleri ve önceki ticari dönüşümler, operasyonel bir denetimle önceden tespit edilebilecek mevcut ve öngörülebilir durumlardır.

Ana şokun hemen ardından Avrupa yakası ilçelerinde dakikalar içinde ses ve SMS iletişimini olanaksız kılan şebeke tıkanıklığı ise, 1999'dan bu yana kayda değer her Türkiye depreminin ardından belgelenmiş olmasına rağmen 26 yıldır çözüme kavuşturulmamıştır. Resmi iletişimde de sıkıntılar olmuştur: 23 Nisan'da Millî Eğitim Bakanı'nın "okullarımızın hiçbirinde herhangi bir sorun yok" şeklindeki açıklaması, bir hafta içinde dört okulun yapısal gerekçelerle tahliye edilmesiyle çelişmiştir.

Bileşik Mekânsal Kırılganlık

2025'te en yüksek bina hasar raporu yoğunluklarının kaydedildiği ilçeler – Bahçelievler, Esenler, Bağcılar, Zeytinburnu, Avcılar, Esenyurt – aynı zamanda kişi başına en düşük toplanma alanına, yumuşak alüvyal zemin üzerinde en yüksek oranda 1999 öncesi betonarme çerçeve bina stoğuna, sismik risk kaynaklı göçün ardından en yüksek düşük gelirli hane yoğunluğuna, en düşük kentsel dönüşüm programı benimseme oranına ve – kritik olarak - DASK'ın yetersiz kaldığında sigortasız onarım maliyetlerini karşılayacak kaynaktan en yoksun nüfusları barındıran ilçelerdir. Bu mekânsal çakışma tesadüf değildir; altmış yıllık kentleşme dinamiklerinin, mevzuata uyumsuzluğun, yapı aflarının ve deprem riskine verilen konut piyasası tepkilerinin bir ürünüdür. 2025 depremi bu örüntüyü yaratmamıştır — kayıtlı yer hareketlerinin tüm istasyonlarda DD-2 tasarım düzeyinin belirgin biçimde altında kaldığı koşullarda, onu doğrulamıştır.

Hazırlık Açığı

Bu raporda belgelenen başarısızlıklar yasal düzenlemelerle ilgildir. Toplanma alanlarına hukuki koruma sağlanması ve operasyonel denetim yapılması, DASK tenzil muafiyeti yapısının ve teminat tavanlarının güncellenmesi, kentsel dönüşüm programının en yüksek riskli ilçelere öncelik verecek şekilde yeniden yönlendirilmesi ve yıkıp yeniden yapıma tanınan destekle eşdeğer güçlendirme sübvansiyonları sunulması, telekomünikasyon altyapısı için deprem sonrası dayanıklılık standartlarının belirlenmesi ve 2025 depreminin Küçükçekmece'de görünür kıldığı inşaat kusurlarını tespit edebilecek bina denetim uygulama mekanizmalarının güçlendirilmesi gibi ihtiyaçların tümü yetkili kurumların mevcut yetki çerçevesinde hayata geçirebileceği adımlardır. Bu adımlar, 1999'dan bu yana uygulanabilir seçenekler olarak mevcuttur. Elazığ 2020, İzmir 2020, Düzce 2022 ve Marmara 2025'ten oluşan ardışık orta büyüklükteki olaylar boyunca esas itibarıyla hayata geçirilmemiş oldukları kayıt altına alınmıştır. Bu rapor da, Mayıs 2026 itibarıyla neler bilindiğini ve nelerin hâlâ çözüme kavuşturulmadığını somut, belgelenmiş ve tarihlendirilmiş biçimde ortaya koymaktadır. Aşağıdaki sekiz ana bulgu, raporun temel tespitlerini özetlemektedir.

Ana Bulgular

AB1. 2025 kırılması, Prens Adaları segmentinde büyük bir depremin olasılığını azaltmamış; kademeli olarak artırmıştır. Kumburgaz segmenti, 1766'dan bu yana biriken gerilimin yaklaşık %8'ini serbest bırakmış ve İstanbul'un güneyindeki kilitli Prens Adaları segmentine doğru gerilim aktarmıştır. Artçı sarsıntılar ilk 24 saat içinde bu segmente doğru doğuya göç etmiştir. Olasılıksal tahminler, önümüzdeki on yıllarda Prens Adaları segmentinde Mw≥7 kırılma olasılığını %35–70 arasında göstermektedir. Bilimsel kanıtlar, 2025 olayının bu tehlikeyi hafifletmek yerine kademeli olarak artırdığına işaret etmektedir.

AB2. En çok etkilenen Avrupa yakası ilçelerindeki bina stoğu gerçek anlamda test edilmemiştir, dolayısıyla 2025 depremindeki yapı davranışına dayanarak bir büyük Istanbul depremi altında yapı hasarının sınırlı kalacağı söylenemez. Kaydedilen yer hareketleri tüm istasyonlarda DD-2 tasarım düzeyinin belirgin biçimde altında kalmış; Avcılar'da tasarım tepe yer ivmesinin yaklaşık %20'si, Küçükçekmece'de ise yaklaşık %52'si kaydedilmiştir. Aydoğdu ve İlki (2026), sınırlı hasarın yapısal yeterliliği değil kısa 13 saniyelik yer hareketi süresini yansıttığını; aynı binaların benzer tepe yer ivmesine sahip daha uzun süreli bir kayıt altında ayakta kalamayacağını ortaya koymaktadır. Eşdeğer TDOF analizleri, tasarım altı yüklemede kırılgan bina tiplerinde halihazırda elastik ötesi talebe ulaşıldığını doğrulamaktadır – dolayısıyla yapı stoğunun bütünü gerçek anlamda test edilmemiş olsa da, en kırılgan kesimi bu deprem altında dahi elastik ötesi davranış sergilemeye başlamıştır. Avcılar, dört istasyon arasında hem en yüksek elastik ötesi talep aşım oranlarını hem de en uzun kuvvetli yer hareketi süresini (40,68 s'ye kadar D5-95) kaydetmiş olup bu durum, uzun süreli büyük bir olayın tam olarak açığa çıkaracağı bileşik yapısal kırılganlığa işaret etmektedir. Deprem aynı zamanda küçük bir tsunami üretmiştir (maksimum 6 cm); senaryo modelleri büyük bir kırılmada Avrupa kıyılarında 3-4 m'ye ulaşan dalgalar öngörmektedir.

AB3. İstanbul'un bina stoğu, mevzuat kaydının çok ötesine geçen gizli kırılganlıklar barındırmakta olup 2025 depremi bu kırılganlıkları gözler önüne sermiştir. İstanbul'da yaklaşık 317.000 bina imar affı yoluyla geriye dönük olarak yasallaştırılmıştır; bunların yaklaşık 90.000'inin ciddi çökme riski taşıdığı düşünülmektedir. Bu eski stoğun durumu 2025 depremi sonrası incelemelerle somut biçimde ortaya konmuştur: Küçükçekmece'de gerçekleştirilen tespitler, mevzuat öncesi dönemi temsil eden binalarda deniz kabuğu parçaları içeren, yani yıkanmamış deniz kumu kullanılarak üretilmiş, temel malzeme standartlarını karşılamayan betona sahip betonarme kolonları belgelemiştir; bu kusur, tasarım düzeyi altı yükleme koşullarında tespit edilmiştir. Yeni yapı üretimine yönelik 1999 sonrasında uygulamaya konan üçüncü taraf bina denetim sistemi ise sözleşme modeli nedeniyle yapısal olarak zayıf kalmakta ve titiz saha denetimi yerine masa başından onay vermeyi teşvik etmektedir. 1999 depremlerinde orta hasarlı olarak tescil edilen binaların bir bölümünün, hukuki takviye süreleri 2020'de dolmuş olmasına karşın 23 Nisan 2025 itibarıyla hâlâ kullanımda oldukları görülmüştür.

AB4. İstanbul'un kentsel dönüşüm programı, doğru binaları hedeflememekte, doğru yöntemleri uygulamamakta ve kaynakları en yüksek riskli ilçelere yönlendirememektedir. Belirlenen yapıların yalnızca yaklaşık %10'unun yıkılmak yerine yapısal güçlendirme yoluyla yeterli performans düzeyine kavuşturulmakta oldukları belgelenmiştir; oysa güçlendirme, kırılgan stoğun önemli bir bölümü için teknik olarak uygulanabilir ve tam yenilemenin gömülü karbon maliyetinin %20-40'ına karşılık gelen bir seçenektir. Programın finansal teşvik yapısı sistematik biçimde istismar edilmektedir: inşaat şirketleri 1999 öncesi binalarda tek bir daire satın alarak risk tespiti başvurusunda bulunmakta, elde edilen tespiti yıkımı dayatmak ve yeniden yapım sözleşmesi ile daire hakkını güvence altına almak için kullanmaktadır – bu uygulama *deprem korkutmacılığı* olarak belgelenen yaygın bir örüntüdür. Bu durum, program aracılığıyla, yüksek riskli bölgeler yerine yüksek arazi değerine sahip ilçeleri önceliklendirildiğini göstermekte ve düşük gelirli haneleri en savunmasız alanlara yönelten bir soylulaştırma sürecini hızlandırmaktadır. 2025 olayının ardından program, Yarısı Bizden girişimi kapsamında genişletilmiş olsa da, mevcut teslim hızında, İstanbul genelinde sayısı 600.000'i aşan yüksek riskli konut biriminin bir sonraki orta büyüklükteki olaydan önce bile kayda değer ölçüde güvenli hale getirilmesi mümkün görünmemektedir.

AB5. Tek bir ölüme yol açan bir depreme verilen İstanbul'un toplumsal tepkisinin ölçeği, orantısız bir paniği değil; kronik olarak yüksek bir deprem korkusunu ve rasyonel risk değerlendirmesini yansıtmaktadır. 2025 Marmara Depremi'nin ardından tahminen 100.000 kişi açık alanda geceyi geçirmiş, şehirlerarası otobüs ücretleri üç katına çıkmış, sağlam zemin ilçelerindeki kira fiyatları saatler içinde %100'ün üzerinde artmıştır. EMSC tarafından gerçek zamanlı olarak toplanan DKÖ verileri onlarca yıllık birikimli sismik risk farkındalığı ve 2023 Kahramanmaraş dizisinin doğrudan deneyimiyle şekillenmiş kronik olarak yüksek bir korku temel düzeyine işaret etmektedir. Açık alanda barınma, bina kırılganlığına dair algıya göre mekânsal olarak sıralanmıştır: bu, rastlantısal bir panik değil, rasyonel bir toplumsal tepkidir.

AB6. Nominal olarak İstanbul nüfusunu depreme karşı korumak için tasarlanmış dört kurumsal çerçeve orta ölçekte test edilmiş, yetersiz kalmış ve her birinde önceki afetlerin ardından da belgelenen başarısızlıklar yinelenmiştir. Toplanma alanı sistemi işlevsel olarak başarısız olmuştur: resmi olarak belirlenmiş alanlar polisçe kapatılmış, şantiyeler tarafından işgal edilmiş ya da hiç mevcut olmamıştır. DASK, bu olayın ürettiği hasar kategorisi için anlamlı bir finansal koruma sağlayamamıştır. Konut piyasası, kırılgan nüfusların en yüksek riskli ilçelerdeki en savunmasız yapı stoğunda yoğunlaşmasını hızlandırmıştır. 1999'dan bu yana kayda değer her Türkiye depreminde belgelenen ve hâlâ çözüme kavuşturulmayan bir açık olan mobil telekomünikasyon doygunluğu ana şokun hemen ardından iletişimi devre dışı bırakmıştır. Millî Eğitim Bakanı'nın 23 Nisan'da "okullarımızda herhangi bir sorun yok" şeklindeki açıklaması ise bir hafta içinde dört okulun yapısal gerekçelerle tahliye edilmesiyle çelişmiştir.

AB7. İstanbul'un sismik riskinin fiziksel, sosyal ve kurumsal boyutları mekânsal olarak üstüste binmekte ve birbirini güçlendirmektedir. En savunmasız bina stoğuna, en az toplanma alanına, en yüksek düşük gelirli hane yoğunluğuna, en düşük kentsel dönüşüm programı benimseme oranına ve sigortasız onarım maliyetlerini karşılayacak en az kaynağa sahip nüfusları barındıran ilçeler aynı ilçelerdir. Bu örüntü rastlantısal değildir: deprem riski farkındalığı yüksek gelirli haneler daha güvenli olarak algılanan bölgelere göç ederken konut piyasası dinamikleri ve kentsel dönüşüm programının soylulaştırma etkisi, düşük gelirli haneleri giderek en yüksek riskli Avrupa yakası ilçelerinde yoğunlaştırmaktadır. Büyük bir depremin sonuçlarını en az kaldırabilecek olanlar, bu sonuçların en ağır biçimde hissedileceği yerlerde birikmektedir.

AB8. Bu raporda belgelenen başarısızlıklar yeni düzenlemelerle giderilebilir niteliktedir; yeni mühendislik bilgisine ya da yeni kurumsal yapılanmaya gerek duymamaktadır. Toplanma alanlarına hukuki koruma sağlanması ve operasyonel denetim yapılması, DASK tenzil muafiyeti yapısının ve teminat tavanlarının güncellenmesi, kentsel dönüşüm programının en yüksek riskli ilçelere yönlendirilmesi ve yıkıp yeniden yapıma tanınan destekle eşdeğer güçlendirme sübvansiyonlarının sunulması, telekomünikasyon dayanıklılık standartlarının belirlenmesi ve bina denetim uygulamasının güçlendirilmesi; yetkili kurumların mevcut yetki çerçevesinde 1999'dan bu yana gerçekleştirebileceği adımlardır. Bu adımlar dört ardışık orta büyüklükteki Türkiye depreminde – Elazığ 2020, İzmir 2020, Düzce 2022 ve Marmara 2025 – hayata geçirilmemiş olarak kalmıştır.

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Ground motion data were obtained from the Turkish Accelerometric Database and Analysis System (TADAS), operated by the Disaster and Emergency Management Presidency (AFAD), and from the Engineering Strong Motion Database of ORFEUS (ESM) and IRIS. Building damage and assessment data were provided by the Ministry of Environment, Urbanisation and Climate Change of the Republic of Türkiye. Assembly area and building stock data were sourced from the Istanbul Metropolitan Municipality (IBB) open-data portal and the Istanbul Planning Agency (IPA).

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1. Introduction

The Earthquake Engineering Field Investigation Team (EEFIT) of the Institution of Structural Engineers (IStructE) conducts post-earthquake field investigations to document the engineering and societal impacts of significant earthquakes worldwide, maintaining a longitudinal record that informs both research and practice. The Mw 6.2 earthquake of 23 April 2025 – the 2025 Marmara Sea or Silivri earthquake – produced no structural fatalities, no collapse of inhabited buildings of consequence, and no failure of major infrastructure. By the engineering metric of damage, it was unremarkable. Yet it occurred immediately offshore from a metropolitan region of approximately 16 million people, on a fault segment whose locked neighbour – the Princes' Islands segment, less than 30 km from Istanbul's historic peninsula – has not ruptured since 1766 and is widely held to be capable of a Mw 7+ event in the coming decades. Probabilistic studies place the likelihood of such a rupture at 35-70% over the coming decades (Parsons et al., 2000; Murru et al., 2016; Bohnhoff et al., 2013); scenario loss studies estimate it could cause between 14,000 and 87,000 fatalities depending on time of day and methodology (IMM and JICA, 2002; IMM and KOERI, 2019). This anticipated major event is the reference frame against which the 2025 earthquake and Istanbul's preparedness are assessed throughout this report.

The disproportion between modest physical damage and a substantial societal response – 100,000 people sleeping outdoors despite minimal structural damage, systematic failures in the assembly area system and economic protection instruments, and evidence with direct implications for Istanbul's future preparedness - justified a dedicated EEFIT study. The 2025 Marmara Sea earthquake is a low-cost rehearsal for a much larger anticipated event, and the records it produced from one of the world's densest strong-motion networks constitute a dataset of enduring scientific value.

This is a desk-based reconnaissance: no EEFIT field mission was deployed to Istanbul in the aftermath of the earthquake, and no local team members were formally engaged. It should be noted, however, that members of the author team were present in Istanbul on 23 April 2025, and first-hand observations made on that day – including structural damage to the Cerrahpaşa Medical Faculty Hospital complex and the precautionary closure of the Tünel funicular – are cited where relevant in this report. Analyses are assembled from the AFAD-TADAS strong-motion database, the AFAD earthquake catalogue, international repositories (ORFEUS, IRIS), the Istanbul Metropolitan Municipality's open-data portal, and published rapid assessments from Turkish and international research groups. Original analyses include a unified 212-station ground-motion dataset (Chapter 2), a building stock regulatory compliance assessment mapped against Istanbul's macroform (Chapter 3), an ESDOF-based urban damage prediction (Chapter 5), a critical assessment of Istanbul's seismic risk mitigation programme including urban transformation policy, retrofit practice and societal costs (Chapter 4), and a spatial analysis of the city's assembly area system and its real-world performance on 23 April (Chapter 9). A systematic social media evidence log (70 entries, Annex), compiled by members of the author team in the weeks following the earthquake, and three crowdsourced datasets provided by the European-Mediterranean Seismological Centre (EMSC) – felt intensity reports, Fear of Earthquake Scale responses, and geolocated photo and video metadata – provide independent evidence on societal response, shaking perception and institutional performance across Chapters 6, 7 and 8. The EMSC Fear of Earthquake Scale dataset represents, to the authors' knowledge, the first application of this psychometric instrument to real-time data collected within hours of an earthquake.

2. Characterisation of the Event

Chapter summary in plain terms

This chapter analyses the ground shaking produced by the 23 April 2025 earthquake using data from 212 recording stations across the Marmara region – one of the densest instrumental records ever collected for a moderate urban earthquake. Ground accelerations remained well below the levels buildings in Istanbul are designed to withstand (20–52% of DD-2 code values). However, the European side of Istanbul experienced systematically stronger shaking than the Asian side, a pattern confirmed independently by instrumental data, official damage reports and crowdsourced felt intensity reports, and attributable in part to softer soil conditions and possible basin or directivity effects. Despite generally falling within median ±2σ bounds, median PGA estimations from KAAH15 exhibit consistent underestimation, with implications for the regional hazard basis. The earthquake also generated a minor, non-damaging tsunami (max. 6 cm); worst-case scenario models suggest waves of 3-4 m at the European coastline under a major rupture, compounding the ground motion hazard in the same districts. The aftershock sequence migrated eastward toward the locked Princes' Islands segment, consistent with a broader 15-year eastward migration of seismicity toward that segment. The earthquake released only approximately 8% of the strain accumulated on the fault since 1766; scientific evidence indicates the 2025 event has incrementally increased, rather than reduced, the likelihood of the anticipated major earthquake on the Princes' Islands segment south of Istanbul.

2.1 Introduction

The Marmara Region is one of the most seismically active and densely populated areas in Türkiye, where the occurrence of a major earthquake would have widespread regional consequences. The level of risk is further heightened by the concentration of major urban centres, most notably Istanbul, which is located along the northern coast of the Marmara Sea. In addition to being located in a high seismic hazard region, Istanbul is the country's largest metropolitan area, with a population approaching 16 million (TÜİK, 2026) and has significant levels of vulnerable infrastructure. Istanbul exemplifies the high level of exposure and vulnerability within the Marmara Region. This combination of high seismic hazard and dense population underscores the critical importance of the region in terms of earthquake risk and potential impact.

The occurrence of a moderate-magnitude (Mw 6.2) earthquake on April 23rd, 2025, along the North Anatolian Fault Zone (NAFZ), which extends approximately in an east-west (EW) direction beneath the Marmara Sea, is of considerable importance. This event provides valuable insight into the ongoing seismic activity of the region particularly given the well-documented potential for a future large-magnitude earthquake along the same fault zone in the Marmara Region. As such, even moderate events play a critical role in improving our understanding of fault behaviour and regional seismic hazard.

This chapter summarises the geology and tectonic history and geology of the region as well as its local seismicity. Following a brief evaluation of the event characteristics and aftershock distribution, the main characteristics of the strong ground motions recorded by different networks are examined and the actual ground motion parameters are compared with the corresponding estimates obtained from a regionally applicable Ground Motion Model (or Ground Motion Prediction Equation – GMPE).

2.2 Geology and Tectonics

The tectonics of Türkiye are defined by its position in the complex collision zone among the Eurasian, Arabian and African plates. The continental collision between the Arabian and Eurasian plates in eastern Anatolia initiates the westward lateral motion of the Anatolian plate, facilitated by two major transform fault systems: the North Anatolian Fault (NAF) and the East Anatolian Fault (EAF). Concurrently, the Hellenic subduction zone generates a pulling force to the west due to the subduction of the African plate beneath the Aegean region (Taymaz et al., 2007; Emre et al., 2018). The tectonic configuration of Türkiye as proposed by Taymaz et al. (2007) is depicted in Figure 1 which shows the main fault zones and plate movement directions. Also, the red rectangle in the figure denotes the Marmara Region including the primary area where the April 23rd event was macroseismically felt based on DYFI (**D**id **Y**ou **F**eel **I**t ?) data of European-Mediterranean Seismological Centre (EMSC-CSEM) and United States Geological Survey (USGS).

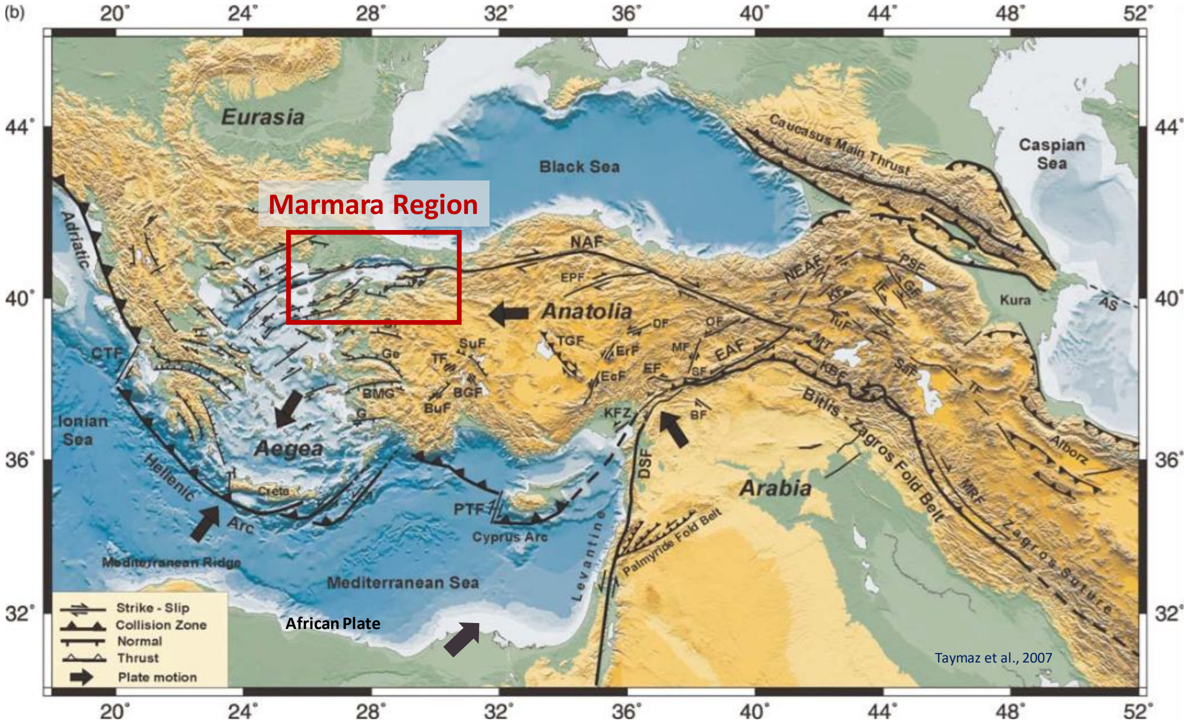
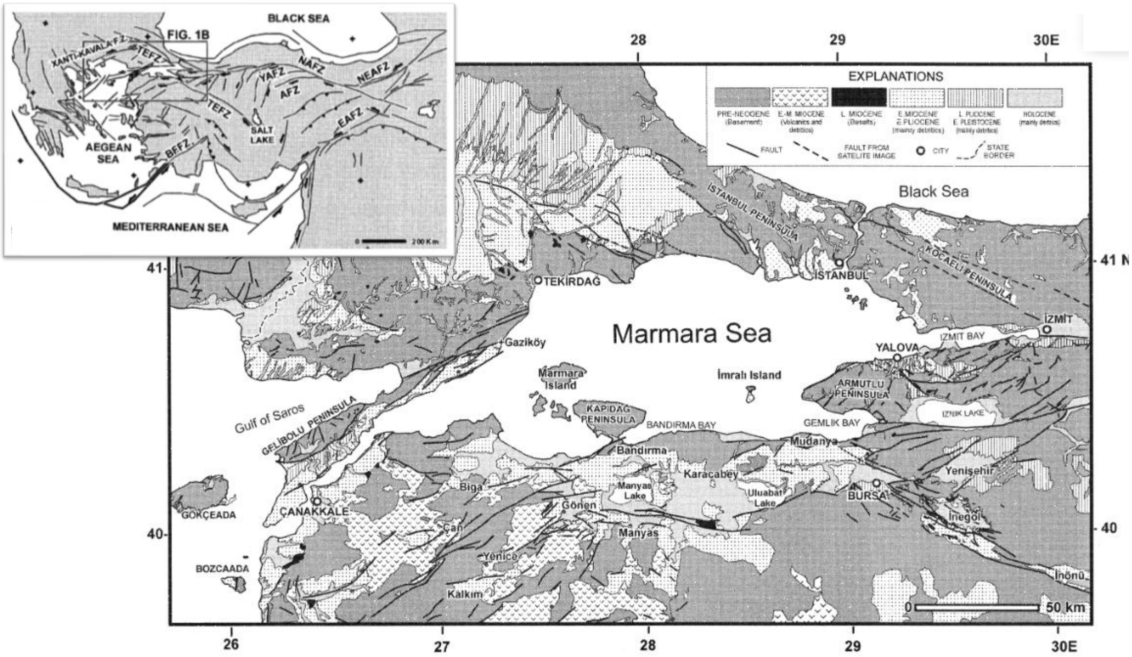


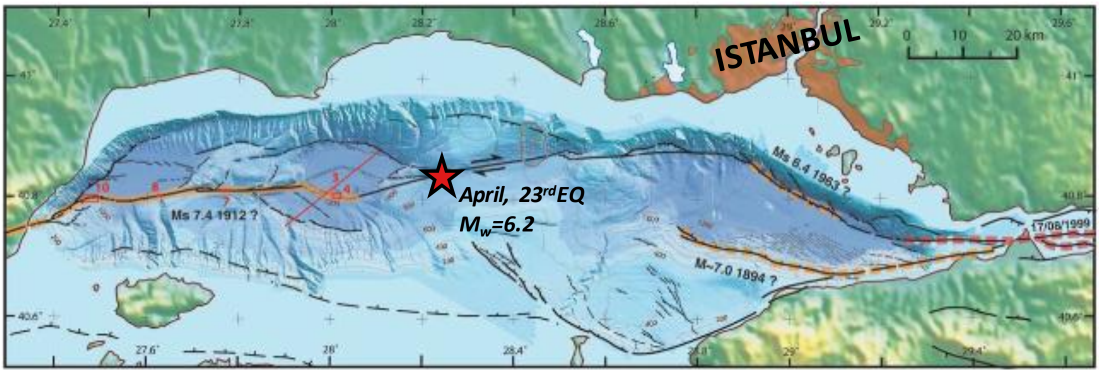
Figure 1: *Tectonic configuration of Türkiye with faulting and bathymetry in the eastern Mediterranean region (NAF :North Anatolian Fault, EAF: east Anatolian Fault; DSF: Dead Sea Fault). Black arrows indicate the direction of plate motion, and red rectangles denote the Marmara Region where the 23 April earthquake was mainly felt (Modified from Taymaz et al., 2007).*

Marmara Region is physically split by the NAF, a right-lateral strike-slip fault extending approximately 1,200-1,400 km from the Karlıova triple junction to the northern Aegean Sea, with slip rates of about 15-25 mm/year. The geology of the Marmara Region (Figure 2a) is characterised by superimposed sedimentary sequences formed during the early Miocene-early Pliocene and late Pliocene-Recent periods. The sedimentary successions of the early Miocene-early Pliocene interval are mainly shaped by the Thrace-Eskişehir Fault Zone (TEFZ) and its westward-branching secondary systems, such as the Ganos, Bandırma-Behramkale and Manyas-Edremit fault zones. Over this period, the Thrace Neogene Basin developed, which consisted of three sub-basins: the Ergene, the Gelibolu-Marmara and the Southern Marmara sub-basins. The North Anatolian Fault Zone (NAFZ) controls the superposition of the Marmara basins onto the sub-basins of the Thrace Neogene Basin. Late Pliocene and younger sediments unconformably overlie the older Thrace Basin fill across much of the region. The NAFZ and its main branches now control the most recent tectonic processes and the evolution of basins in the Marmara Sea (Yaltırak, 2002).

This region marks a tectonic transition zone between relatively stable Anatolian Plate interior and the extensional regime of western Türkiye (Jenkins et al., 2020; Emre et al., 2018). As the NAF enters the Marmara Region, it splits into two principal branches: the northern and southern strands. The northern branch (Figure 2b), extending ~500 km from the Adapazarı Basin to the North Aegean Trough, forms the main tectonic pathway, accommodating most of the plate motion through a complex pull-apart system[1]. This is reflected in the development of the North Marmara Basin, located within the step-over zone between the İzmit and Ganos strike-slip faults. In contrast, the southern branch diverges from the main system, bypassing the central pull-apart structure and exhibiting significantly lower slip rates from the Dokurcun Valley toward Bandırma (Armijo et al., 2005; Emre et al., 2018). A comprehensive description of the source and rupture properties of the 2025 Marmara Sea earthquake 2025 can be found in Eken et al. (2025).



(a)



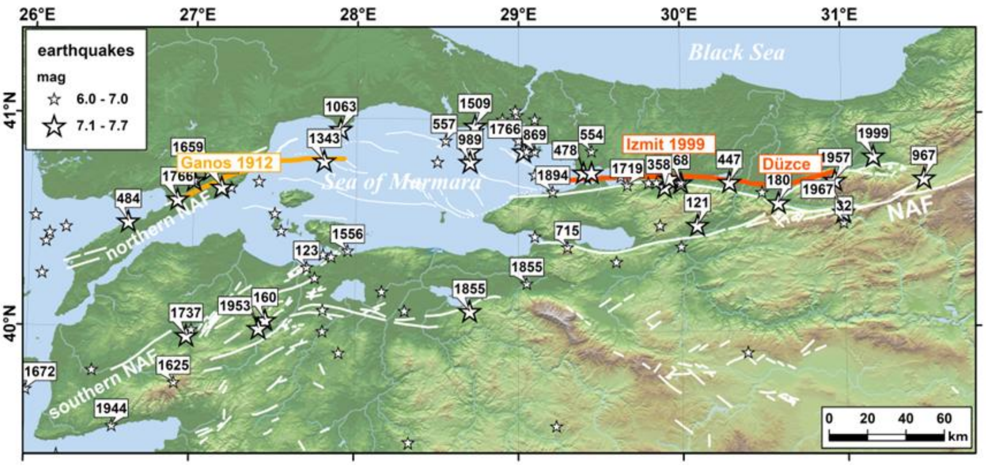
(b)

Figure 2: ***(a)*** *Geological map of the Marmara Region, with a simplified tectonic map of the eastern Mediterranean shown in the top-left inset (Modified from Yaltırak, 2002),* ***(b)*** *Active faulting and seafloor bathymetry within the North Marmara Basin (Modified from Armijo et al., 2005).*

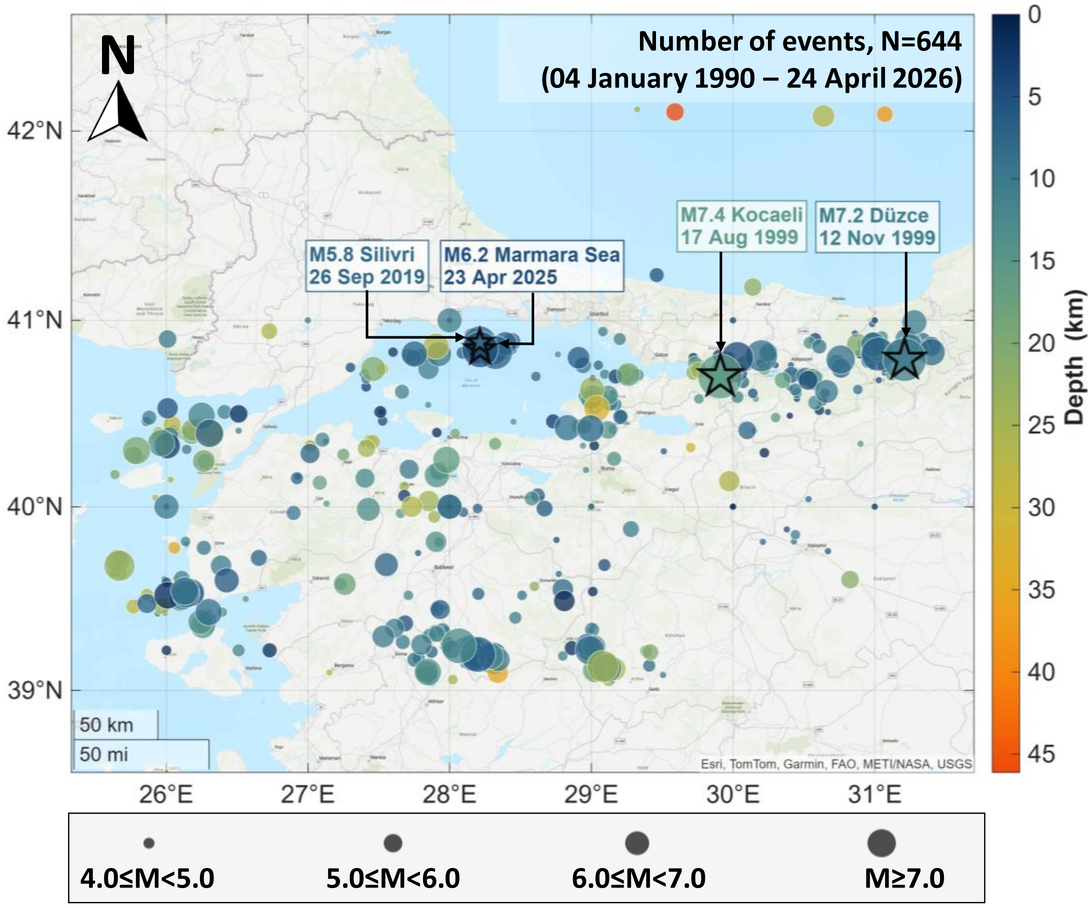
[1] A pull-apart basin forms where a strike-slip fault steps laterally, creating a zone of crustal extension between the offset fault segments. The resulting depression fills with sediment and, in submarine settings such as the Marmara Sea, forms a series of deep bathymetric troughs separated by ridges.

2.3 Local Seismicity

Seismicity in the Marmara Sea region (Figure 3a and b) is largely governed by the NAFZ, which exhibits a well-documented westward migration of large earthquakes (Stein et al., 1997; Şengör et al., 2005).



(a)



(b)

Figure 3: ***(a)*** *Spatial distribution of historical earthquakes in the Marmara region. White lines correspond to active faults according to the General Directorate of Mineral Research and Exploration (MTA) (Italiano et al., 2015),* ***(b)*** *Seismicity (M≥4.0) map of the Marmara region derived from the AFAD earthquake catalogue for the period 4 January 1990-24 April 2026 together with depth. Circle size corresponds to earthquake magnitude whereas colour reflects variations in earthquake depth.*

According to Ambraseys (2002), the Marmara Sea region has experienced 55 large (Ms > 6.8) earthquakes over the past 20 centuries most of which could be seen in Figure 3a and b. In the west of the Marmara Sea, the recurrence interval between the 1509 and 1766 historical earthquakes suggests the presence of a seismic gap of approximately 250 years in the southern vicinity of Istanbul (Bohnhoff et al., 2013). At the vicinity of the 2025 Marmara Sea earthquake, there is no clear evidence of a previous event in the historical record. The closest known earthquake to the epicenter appears to be the 1343 earthquake, which had an estimated magnitude of approximately Ms ≈ 7.0 according to Ambraseys (2002). Figure 3b illustrates the spatial distribution of local seismicity derived from the AFAD earthquake catalogue database for the period 4 January 1990-24 April 2026, including depths.

The dataset comprises a total 644 earthquakes with magnitudes greater than 4. In addition, 119,756 seismic events with magnitudes lower than 4.0 has been detected within the depicted Marmara Region during the same time period. The 1999 earthquakes represent the most recent events in this sequence, involving rupture of the Kocaeli and Düzce segments of the North Anatolian Fault (NAF) with Mw 7.4 and 7.2, respectively. The 2025 Marmara and 2019 Silivri earthquakes were the largest in the Sea of Marmara over the last 60 years.

2.4 Event Characteristics and Aftershocks

On 23 April 2025 at 12:49:10 local time, a moment magnitude, Mw 6.2 earthquake occurred in the Sea of Marmara near the Kumburgaz segment of the North Anatolian Fault (NAF). Magnitude estimates, focal mechanism solutions and depth determinations reported by different agencies are presented Figure 4. AFAD reports the mainshock at 40.8536°N, 28.2264°E with a predominantly strike-slip mechanism inferred from focal solutions. Although small discrepancies exist in the reported coordinates across agencies, the strike-slip dominance remains consistent in all solutions. Magnitudes are consistently estimated at 6.2 by most agencies, except for IPGP whereas depth estimates show notable variability ranging from 4 to 13 km.

Aftershock data were compiled from the AFAD (the Disaster and Emergency Management Authority earthquake catalogue (with records from 1973 onwards). Following the mainshock, more than 600 aftershocks were recorded around the mainshock, with magnitudes varying from 0.7 to 5.9 over the 30-day period spanning 23 April-23 May 2025. Figure 5 shows the statistical distribution of aftershock magnitudes and depths. The median magnitude is approximately 1.9 regardless of magnitude scale type, with the majority of events smaller than M2.0. Aftershock depths range from approximately 1 to 20 km, with a mean depth of about 7 km consistent with the mainshock depth reported by AFAD.

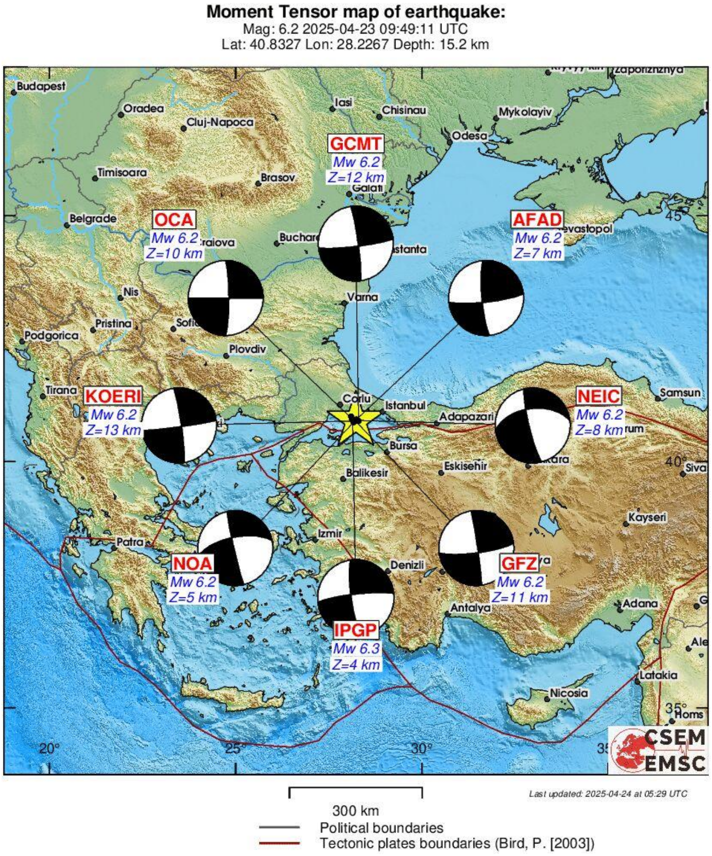


Figure 4: *Magnitude, focal mechanism solutions, and depth estimates from various agencies for the 23 April 2025 Marmara Sea earthquake (Mw 6.2). (AFAD: Disaster and Emergency Management Authority (Türkiye); KOERI: Kandilli Observatory and Earthquake Research Institute (Boğaziçi University, Türkiye); GCMT: Global Centroid Moment Tensor Project; NEIC: National Earthquake Information Center (U.S. Geological Survey, USA); GFZ: German Research Centre for Geosciences (GFZ Potsdam, Germany); IPGP: Institut de Physique du Globe de Paris (France); NOA: National Observatory of Athens (Greece); OCA: Observatoire de la Côte d'Azur (France) (European-Mediterranean Seismological Centre [EMSC], retrieved April 2026).*

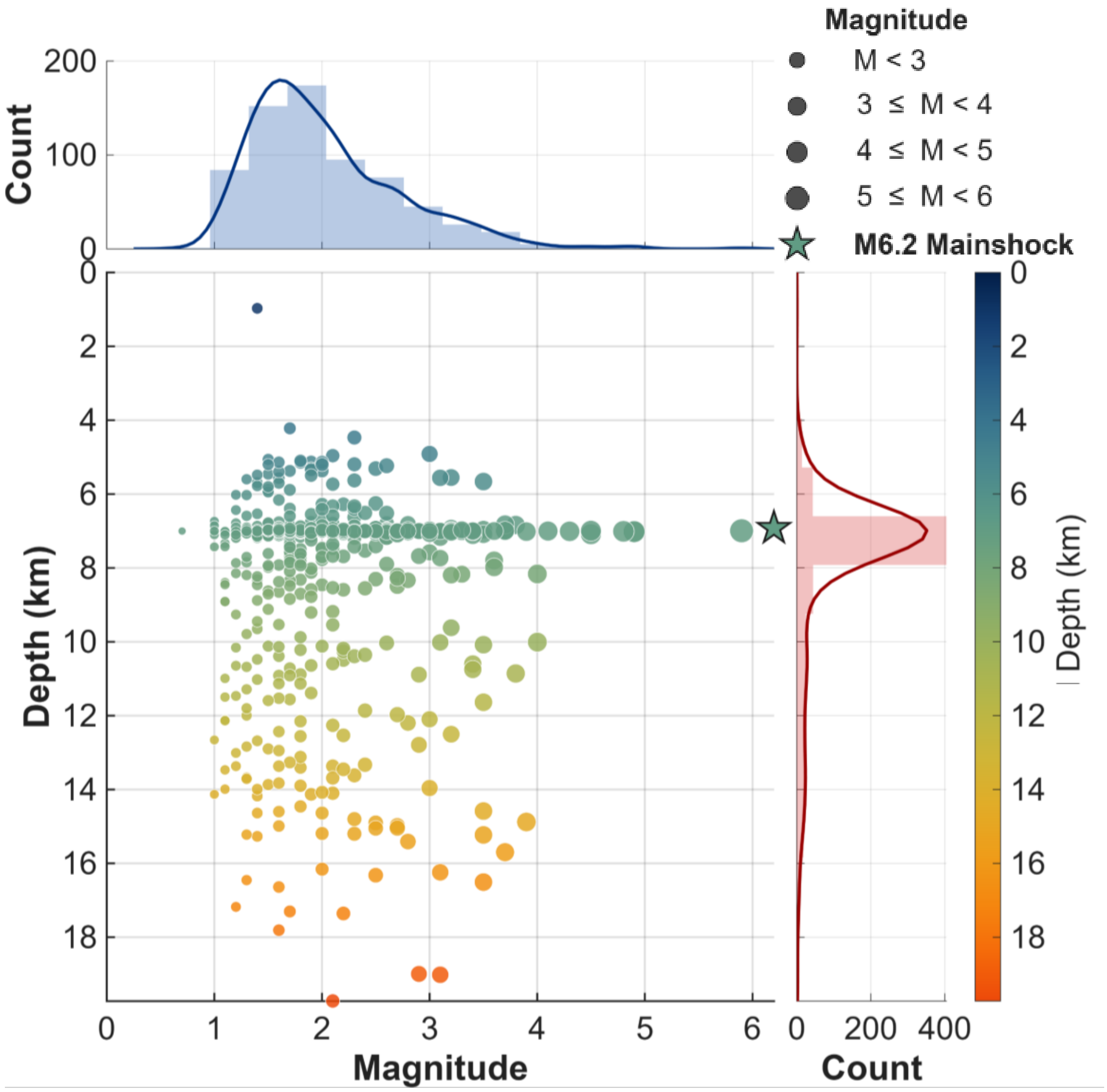


Figure 5: *Statistical distribution of aftershock magnitudes and depths for the Mw 6.2 Marmara Sea earthquake recorded between 23 April and 23 May 2025 in the AFAD earthquake catalogue. Circle size corresponds to earthquake magnitude whereas colour reflects variations in earthquake depth.*

For different magnitude ranges, the spatial distribution of aftershocks is depicted in Figure 6. Approximately two minutes after the mainshock, an aftershock with a magnitude of 5.9 is observed immediately to the east. Furthermore, aftershocks with magnitudes between 3.0 and 5.0 are primarily concentrated to the east of the Mw6.2 Marmara Sea earthquake although only a few events with magnitudes between 3.0 and 4.0 are observed to the west. Although a cluster of smaller events (M < 3.0) exists on the western side, the overall aftershock distribution is dominated by activity to the east.

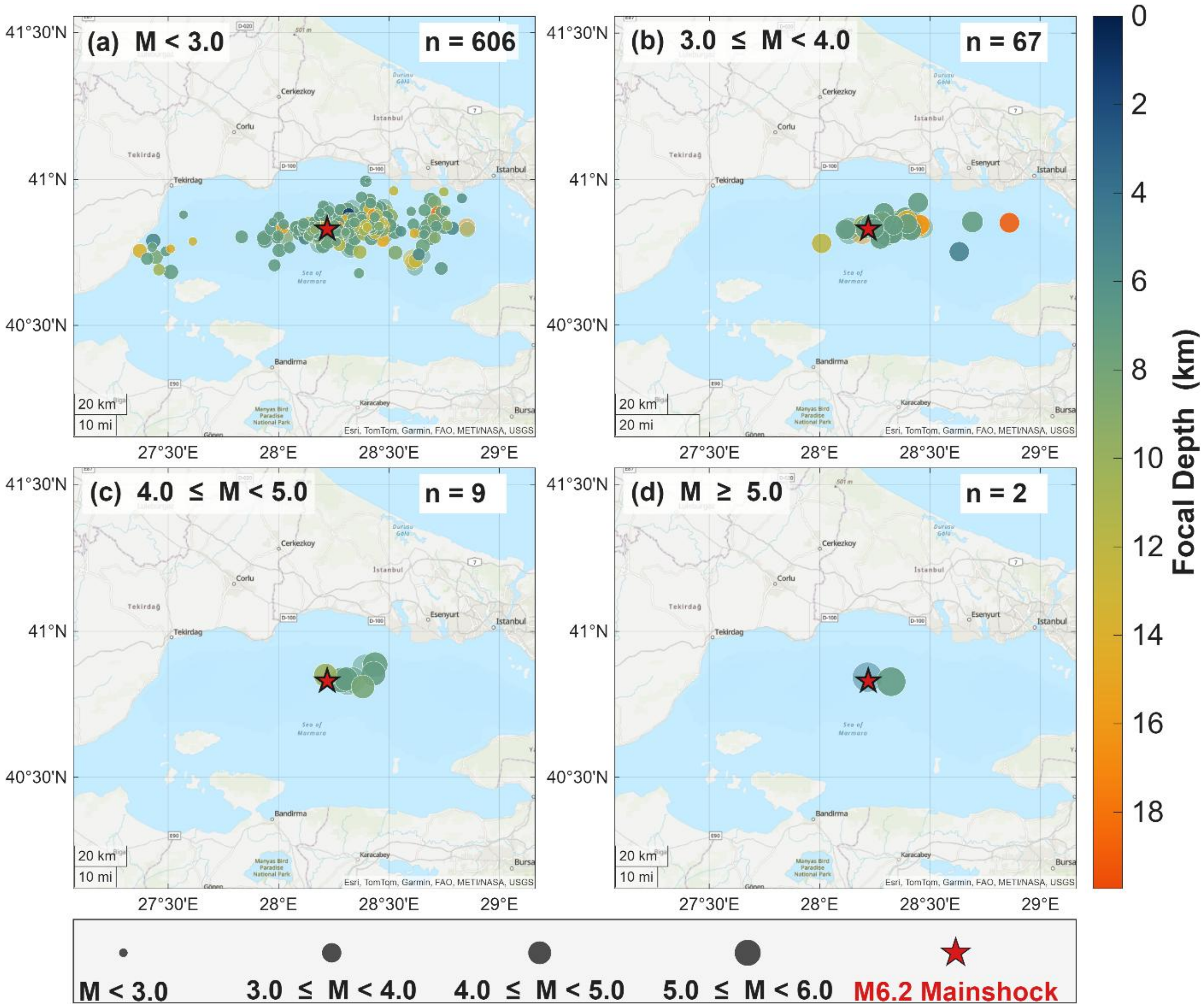


Figure 6: *Spatial distribution of aftershocks associated with the April, 23rd Marmara Sea earthquake (Mw 6.2), recorded over the period 23 April-23 May 2025 based on earthquake catalogue of AFAD. Circle size corresponds to earthquake magnitude whereas colour reflects variations in earthquake depth.*

Ertuncay et al., 2025 presents a rapid assessment of the 2025 Marmara Sea earthquake, including source characterisation, aftershock distribution and ground motion analysis. The study corroborates the eastward propagation of aftershocks and states that this pattern is consistent with the regional tectonic regime and the right-lateral strike-slip kinematics of the North Anatolian Fault (NAF) in line with observations from the 2019 Silivri and 1999 Kocaeli events. Furthermore, Martínez-Garzón et al. (2025) indicate that the migration pattern of seismicity within the Sea of Marmara has reversed over the last 15 years. Rather than migrating westward, a sequence of M > 5 earthquakes together with the 2019 (Mw 5.8 and Mw 4.9) and 2025 (Mw 6.2) events, has propagated eastward toward the locked fault segments south of Istanbul. Despite this reversal, the authors emphasize that a future large earthquake could still originate east of the Marmara Sea (Princes' Islands segment) and propagate westward consistent with the rupture pattern observed during the 20th century.

2.5 Strong Ground Motion Characterisation

2.5.1 Generation of Final Ground Motion Dataset

The Turkish Accelerometric Database and Analysis System (TADAS), operated by the Disaster and Emergency Management Presidency (AFAD), yields relatively dense strong ground motion data in the vicinity of the event from both TK and TU monitoring networks. The ground motion data disseminated through the TADAS website (https://tadas.afad.gov.tr/list-event) has been accessed and retrieved on January 20, 2026 for the April 23rd, 2025, Marmara Sea Earthquake (M_W 6.2).

In addition to the AFAD database, a comprehensive survey of international strong motion repositories, including Incorporated Research Institutions for Seismology (IRIS) (https://ds.iris.edu/wilber3/find_event) and Engineering Strong Motion Database of ORFEUS (https://esm-db.eu/), was conducted on 27 and 30 January 2026, respectively. This extended search identified ground motion records from a total of 105 distinct networks without applying any source-to-site distance criteria and was inclusive of the AFAD data. Then, all identified ground motion data are compiled into a unified dataset. Without imposing any selection criteria, a total of 7667 individual ground motion recordings are obtained.

Since the data from several networks including AFAD are also disseminated through international repositories such as ORFEUS and IRIS via the FDSN, duplicate ground motion records were systematically identified and removed from the initial dataset. Then, the compiled dataset was subjected to a distance criterion. In the analyses presented in this report, the maximum R_{EPI} is restricted to 200 km. Following the distance criterion application, signal quality was assessed through visual inspection of acceleration, velocity and displacement time histories. Recordings exhibiting poor quality such as those containing interruptions in the time series or significant noise contamination that compromises the physical reliability of the signals were identified and excluded from the dataset. Furthermore, as the scope of this study does not encompass vertical ground motion components, only horizontal components were considered during the data quality monitoring and selection process.

The ground motion dataset compiled for this study draws on three networks: the AFAD-TADAS strong-motion network (TK and TU), the Kandilli Observatory and Earthquake Research Institute (KOERI) network (KO) operated by Boğaziçi University, and the Institute of Engineering Seismology and Earthquake Engineering (ITSAK) network (HI) operated from Greece. A total of 212 stations is retained after the selection criteria described below. The number of usable stations in the final database is statistically evaluated in Figure 7 with respect to R_{EPI} with 20 km intervals and network classifications.

A total of 212 stations are included in the final database, the majority of which (approximately 75%) belong to the AFAD-TADAS network (TK and TU). The KOERI network follows contributing 52 stations, corresponding to 24.5% of the dataset. The ITSAK network is represented by a single station in the final ground motion dataset. Furthermore, both AFAD and KOERI stations are distributed across all epicentral distance (R_{EPI}) bins considered in this study. This indicates that, in terms of distance coverage up to 200 km, these two networks provide a relatively homogeneous distribution of ground motion data.

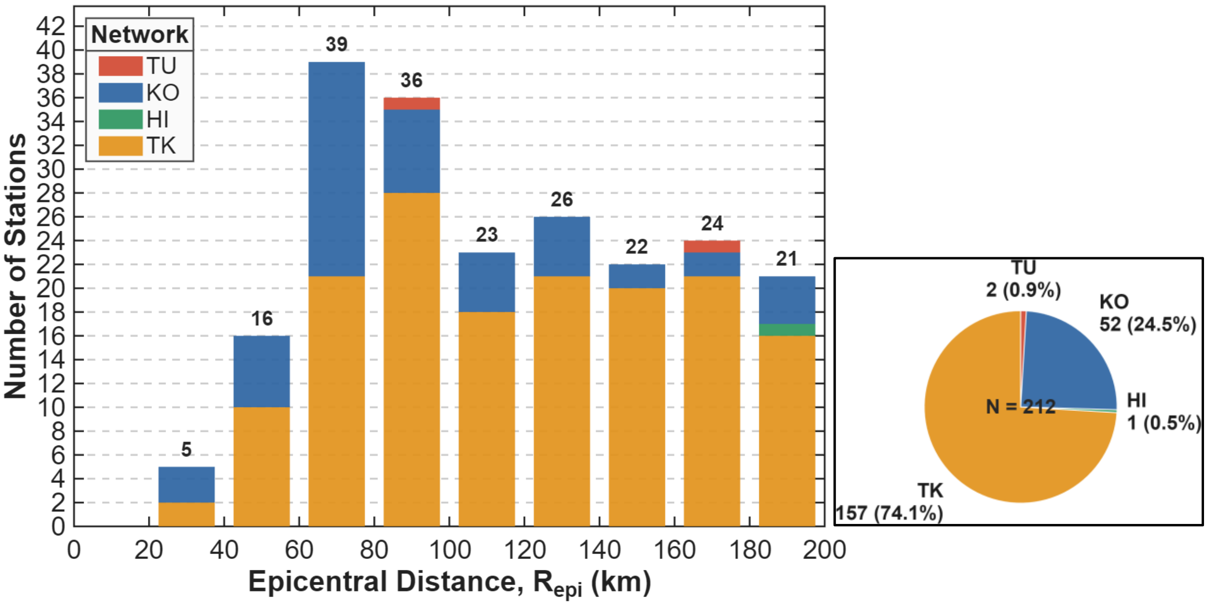


Figure 7: *Statistical distribution of epicentral (R_{EPI}) distances of stations which recorded the M_W 6.2 Marmara Sea earthquake in terms of networks (TU and TK: AFAD-TADAS; KO: KOERI and HI: ITSAK).*

Thereafter, a statistical assessment of the stations is conducted with respect to soil conditions with primary emphasis placed on the average shear wave velocities of the stations for the upper 30 m depth (V_{S30}) reported by the respective networks (Figure 8). However, V_{S30} values are unavailable for a subset of 75 stations. While these recordings are incorporated into analyses that do not depend on local soil conditions, they are omitted from analyses for which soil condition information constitutes a required input such as ground motion model comparisons.

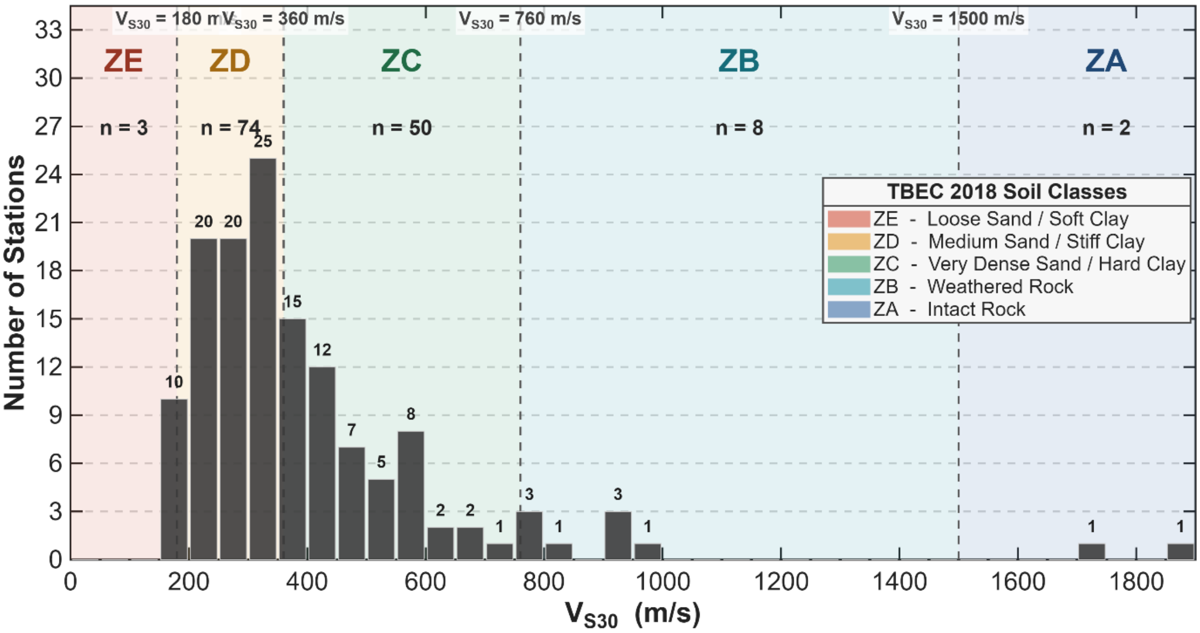


Figure 8: *Distribution of the average shear wave velocities of the stations for the upper 30 m depth (V_{S30}) for the M_W 6.2 Marmara Sea event together with soil classes in the Turkish Building Earthquake Code (TBEC), 2018.*

Thus, the statistical evaluation was performed on the remaining 137 stations for which V_{S30} values has been provided. Figure 8 illustrates the V_{S30} distribution with the bin width of 50 m/s. The same figure also presents the site classification according to the Turkish Building Earthquake Code (TBEC, 2018). The majority of the stations fall within the ZD class (180 m/s<V_{S30}≤360 m/s), including 74 stations. This is followed by the ZC soil class (360 m/s<V_{S30}≤760 m/s) with 50 stations. In contrast, the number of stations (N=3 for ZA, N=8 for ZB and N=2 for ZA) corresponding to the remaining soil classes is relatively limited when compared to the ZC and ZD categories.

As illustrated in Figure 9, the strong ground motion stations of AFAD-TADAS network and KOERI exhibit a well-distributed spatial coverage around the epicentre. Also, it should be noted that the earthquake magnitude and epicentral coordinates utilized in this section of the report are provided by the Kandilli Observatory and Earthquake Research Institute (KOERI).

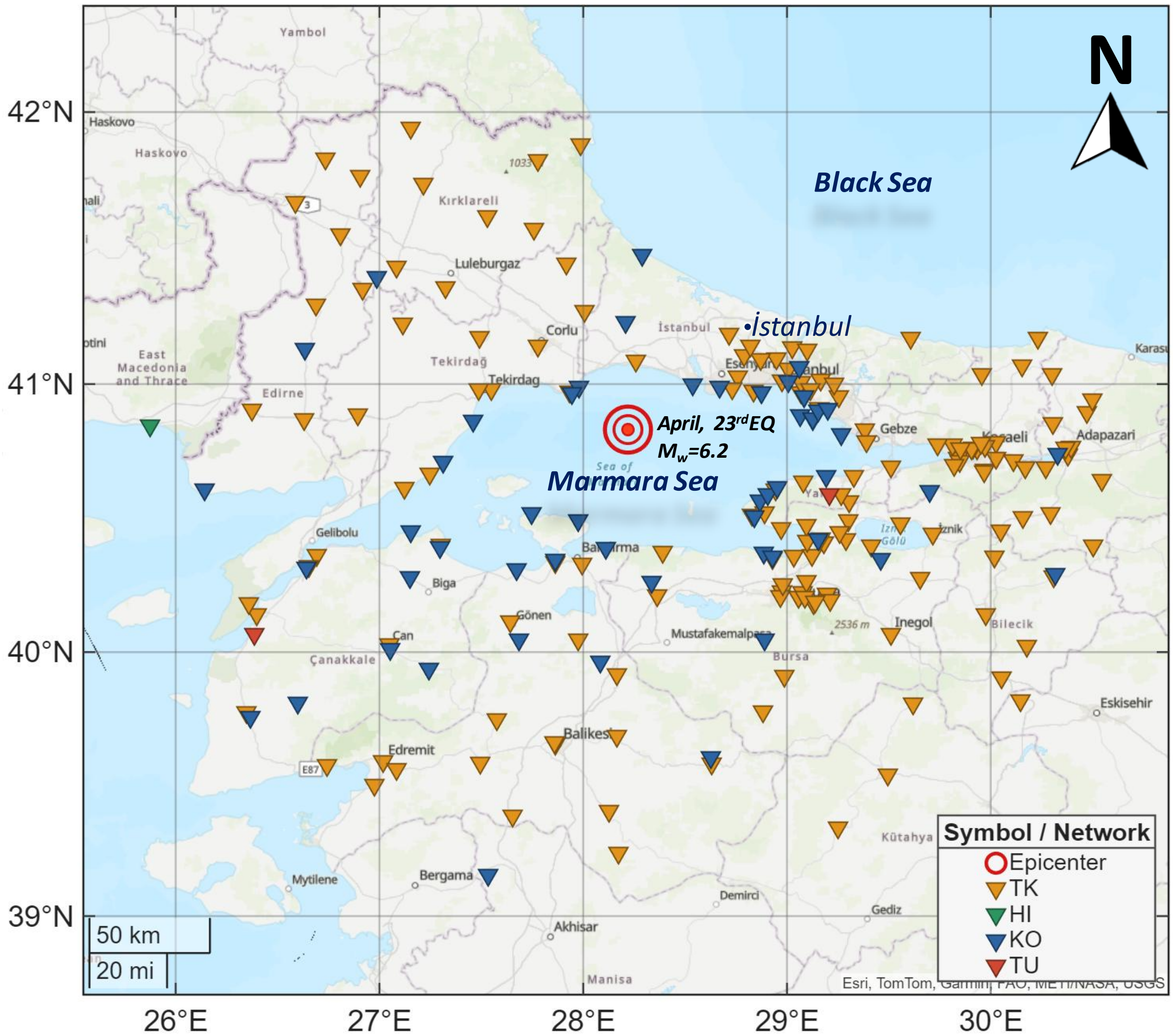


Figure 9: Spatial distribution of strong ground motion stations recording the April, 23rd, 2025 Marmara Sea earthquake (Mw 6.2).

Following the compilation of the resulting dataset, the raw horizontal and vertical components of ground motion recordings has been exposed to a systematic signal processing procedure in order to enhance the data quality and to remove undesirable noise components. Initially, baseline correction has been applied to the data to eliminate long-term drifts. Then, noise has been mitigated by applying a fourth-order Butterworth band-pass filter within a frequency range of 0.01-30 Hz. Following the filtering process, the corresponding velocity and displacement time histories were visually inspected to verify the adequacy of the selected high-pass filter threshold. If necessary, the data has been re-processed with adjusted filter frequencies to ensure the quality of the signals.

2.5.2 Main Characteristics of Ground Motion Parameters

For preliminary assessments of shaking severity, peak ground acceleration (PGA) is one of the most extensively used indicators. Thus, the initial focus is placed on ground motions yielding the highest PGAs. The spatial distribution of PGAs for the EW and NS components together with the corresponding acceleration and velocity time histories is illustrated in Figure 10 and Figure 11, respectively. The maximum horizontal peak ground acceleration (PGA) is observed in the NS component at station 3415 with a value of 211.73 cm/s² (0.22 g). In contrast, the largest PGA in the EW component is recorded at station 3431 with a value of 162.89 cm/s² (0.17 g).

When the geometric mean of PGAs is considered for both stations, station 3415 exhibits a value of 171.2 cm/s² (0.17 g) whereas station 3431 yields a geometric mean PGA of 128.6 cm/s² (0.13 g). Similarly, the geometric mean peak ground velocities (PGVs) are calculated as 7.69 cm/s for station 3415 and 2.74 cm/s for station 3431. Station 3415 is located at an epicentral distance of 48.7 km, while station 3431 is situated 55.25 km from the epicentre. From a distance-based perspective alone, the observed PGA values are consistent with expectations. Furthermore, when site conditions are incorporated through V_{S30} values, this further substantiated. Specifically, station 3415 has a lower V_{S30} (~283 m/s) compared to station 3431 (~566 m/s) indicating softer soil conditions. Therefore, both the shorter epicentral distance and lower V_{S30} value of station 3415 support the higher PGA and PGV observed at this station, despite the fact that the largest EW component PGA is recorded at station 3431. Furthermore, the highest vertical PGA and PGV is recorded at station 3415 with PGA_{UD}=71.08 cm/s^2 and PGV_{UD}=3.07 cm/s, respectively.

Despite the distance-based consistency noted above, the spatial distribution of recorded ground motions (Figure 10 and Figure 11) reveals an apparent anomaly that highlights the role of local site conditions. Station 3429 from the AFAD-TADAS (TK) network, the nearest station to the epicentre with a known V_{S30} value (R_{EPI} = 25.87 km, V_{S30}≈ 230 m/s), recorded a geometric mean PGA of 87.55 cm/s² (0.09 g) and PGV of 5.73 cm/s – both substantially lower than the values recorded at the more distant station 3415 (R_{EPI} = 48.7 km, V_{S30} ≈ 283 m/s), which recorded 171.2 cm/s² (0.17 g) and 7.69 cm/s respectively. The vertical components show the same pattern: vertical PGA and PGV at station 3429 (34.20 cm/s² and 1.66 cm/s) are similarly lower than those at station 3415. Selected ground motion parameters including Arias intensity (I_a), significant duration ($D_{5\text{-}95}$), root mean square acceleration (a_{rms}) and cumulative absolute velocity (CAV) for each component at the three stations are reported in Table 1. All parameters at station 3429 are smaller than those at station 3415, with the exception of $D_{5\text{-}95}$ for the NS component. This pattern – stronger shaking at a more distant station with comparable site conditions – suggests that factors beyond simple distance attenuation and V_{S30}-based site classification, such as basin geometry, source directivity or shallow site-specific amplification, contributed to the elevated ground motions on Istanbul's European side. Station 3428, also frequently referenced in subsequent sections, is notable for its relatively low PGA but long significant duration and higher velocity-related intensity measures, particularly PGV and CAV – a combination relevant to the damage potential for vulnerable low-ductility structures discussed in Chapter 5.

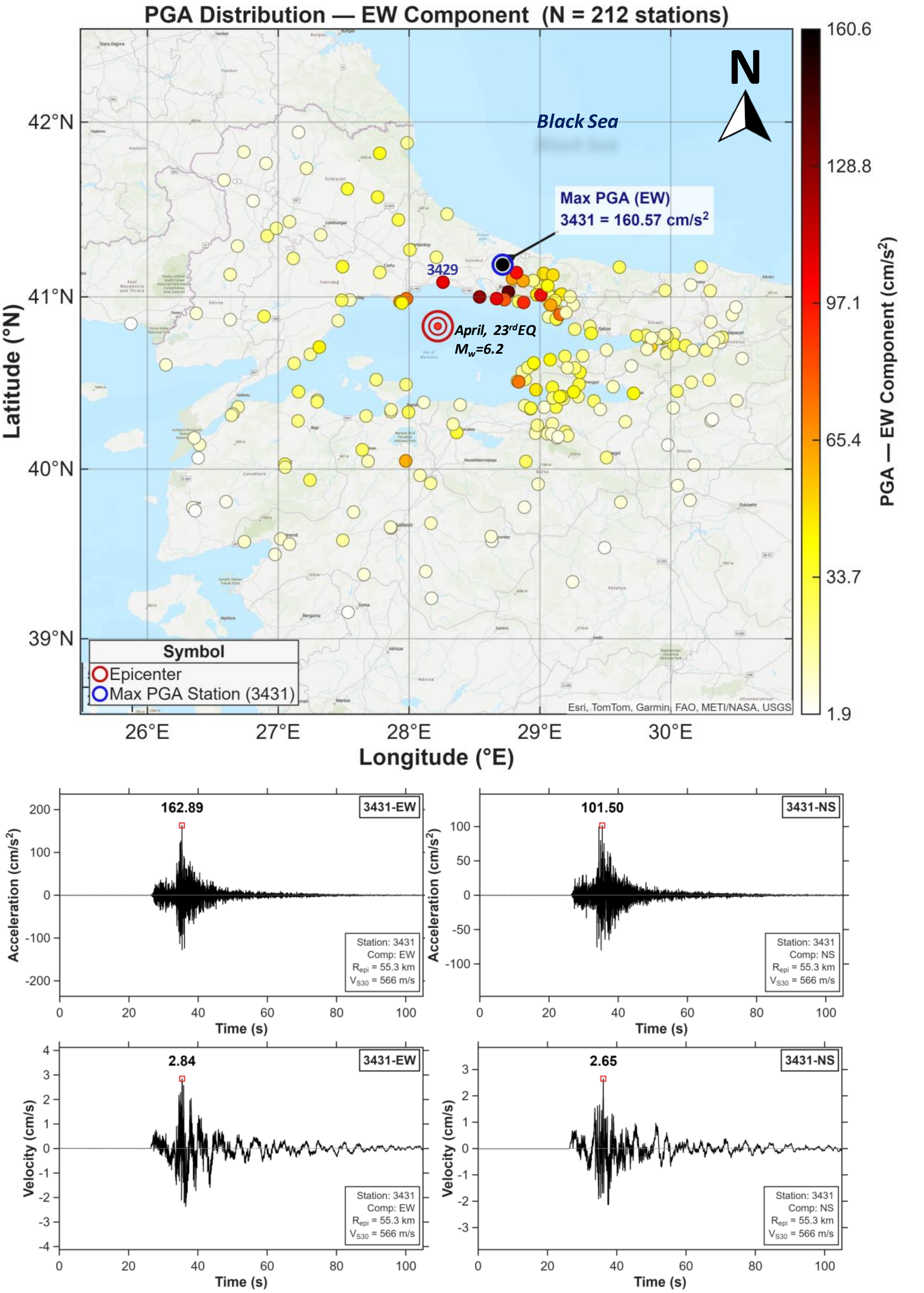


Figure 10: *Spatial distribution of peak ground accelerations (PGAs) for the EW component at the top along with acceleration and velocity time histories corresponding to the maximum EW PGA and PGV (Station:3431) at the bottom.*

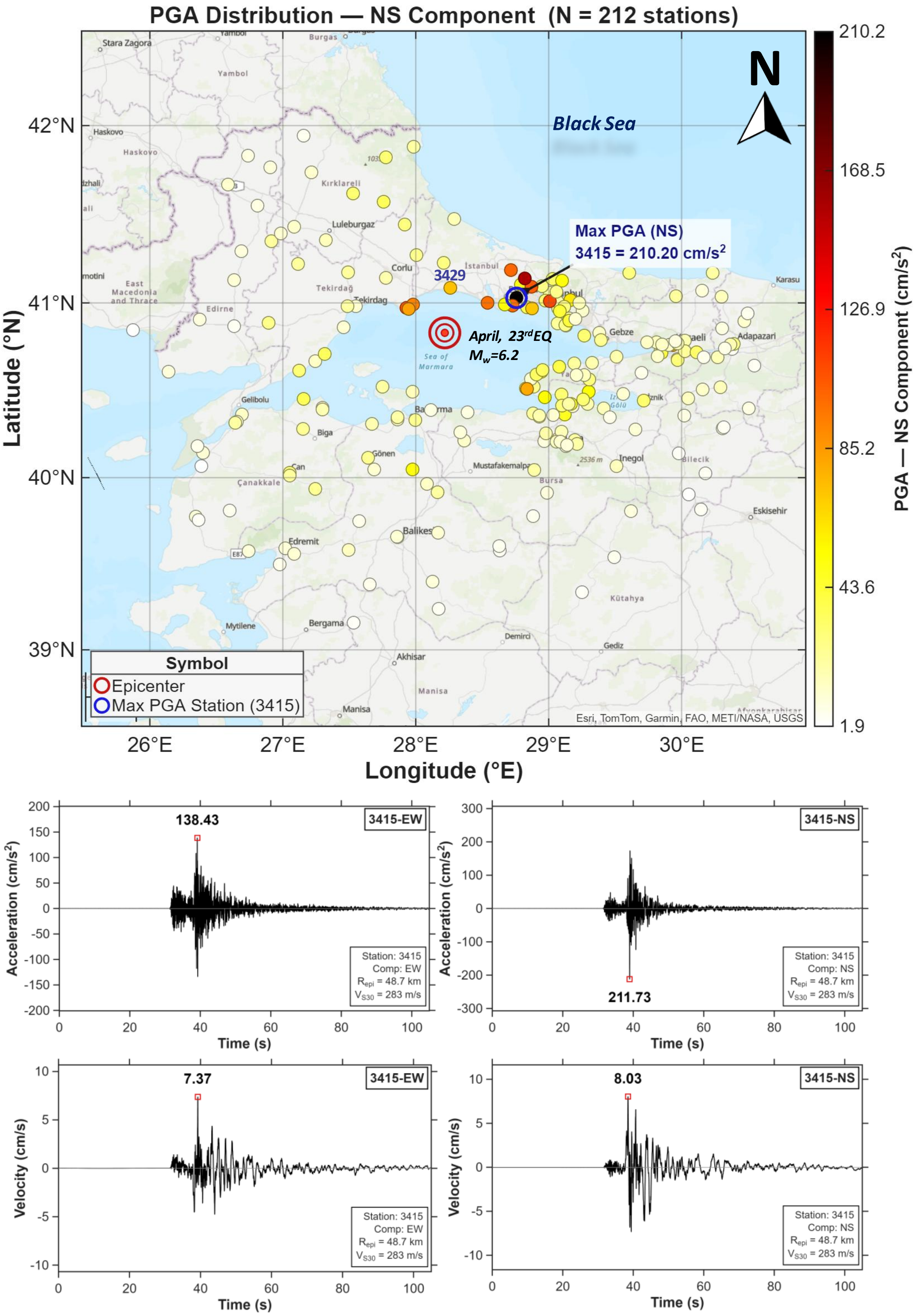


Figure 11: ***(Top)*** *Spatial distribution of peak ground accelerations (PGAs) for the EW component, along with* ***(Bottom)*** *acceleration and velocity time histories corresponding to the maximum EW PGA and PGV (Station:3415).*

Table 1: *Selected ground motion parameters for the EW and NS components at Stations 3415 (Küçükçekmece, REPI = 48.7 km, ZD soil), 3431 (REPI = 55.3 km), 3429 (Silivri, REPI = 25.9 km, ZD soil) and 3428 (Avcılar, REPI = 44.7 km, ZD soil) for the 23 April 2025 Mw 6.2 Marmara Sea earthquake. Parameters reported include peak ground acceleration (PGA), peak ground velocity (PGV), Arias intensity (IA), significant duration (D5-95), root mean square acceleration (aRMS), and cumulative absolute velocity (CAV).*

Station Code	**3415 (*R_{EPI}=48.7 km*)**		**3431 (*R_{EPI}=55.3km*)**		**3429 (*R_{EPI}=25.87km*)**		**3428 (*R_{EPI}=44.72km*)**	
Component	**EW**	**NS**	**EW**	**NS**	**EW**	**NS**	**EW**	**NS**
Peak Ground Acceleration, PGA (cm/s^2)	138.43	211.73	162.89	101.50	105.79	72.45	80.65	97.87
Peak Ground Velocity, PGV (cm/s)	7.37	8.03	2.84	2.65	7.04	4.67	9.93	14.18
Arias Intensity, I_A (cm/s)	16.46	21.98	19.76	9.53	15.00	7.73	13.93	13.45
Significant Duration, $D_{5,95}$ (s)	17.57	10.75	13.73	14.65	17.07	23.70	40.68	32.34
Root Mean Square (RMS) Intensity, a_{RMS} (cm/s^2)	22.95	33.90	28.45	19.12	22.21	13.53	13.87	15.29
Cumulative Absolute Velocity, CAV (cm/s)	418.47	408.33	428.26	306.34	396.31	317.13	512.4	481.67

2.5.3 Comparison with Earthquake Loads in Seismic Code of Türkiye

The assessments in the previous section prompted the authors to examine the PGA and PGV values reported in the Turkish Seismic Hazard Map for these stations. This section first provides a brief overview of the evolution of the Turkish seismic hazard maps and then focuses on the Marmara region with particular emphasis on the stations that released the highest ground motions during the Mw 6.2 Marmara Sea earthquake.

The development of seismic zonation in Türkiye, which initiated in the 1930s (Özmen, 2012), has been shaped by successive revisions following major destructive earthquakes; notably the Ms 6.9 Erzincan (1939), Ms 6.8 Erzincan (1992), Ms 6.1 Dinar (1995), Mw 7.8 Gölcük and Mw 7.5 Düzce (1999) and Mw 7.2 Van (2011) earthquakes. Seismic hazard in Türkiye was defined using zonation-based maps until 2018. The historical development of these maps from 1945 to the present is depicted in Figure 12.

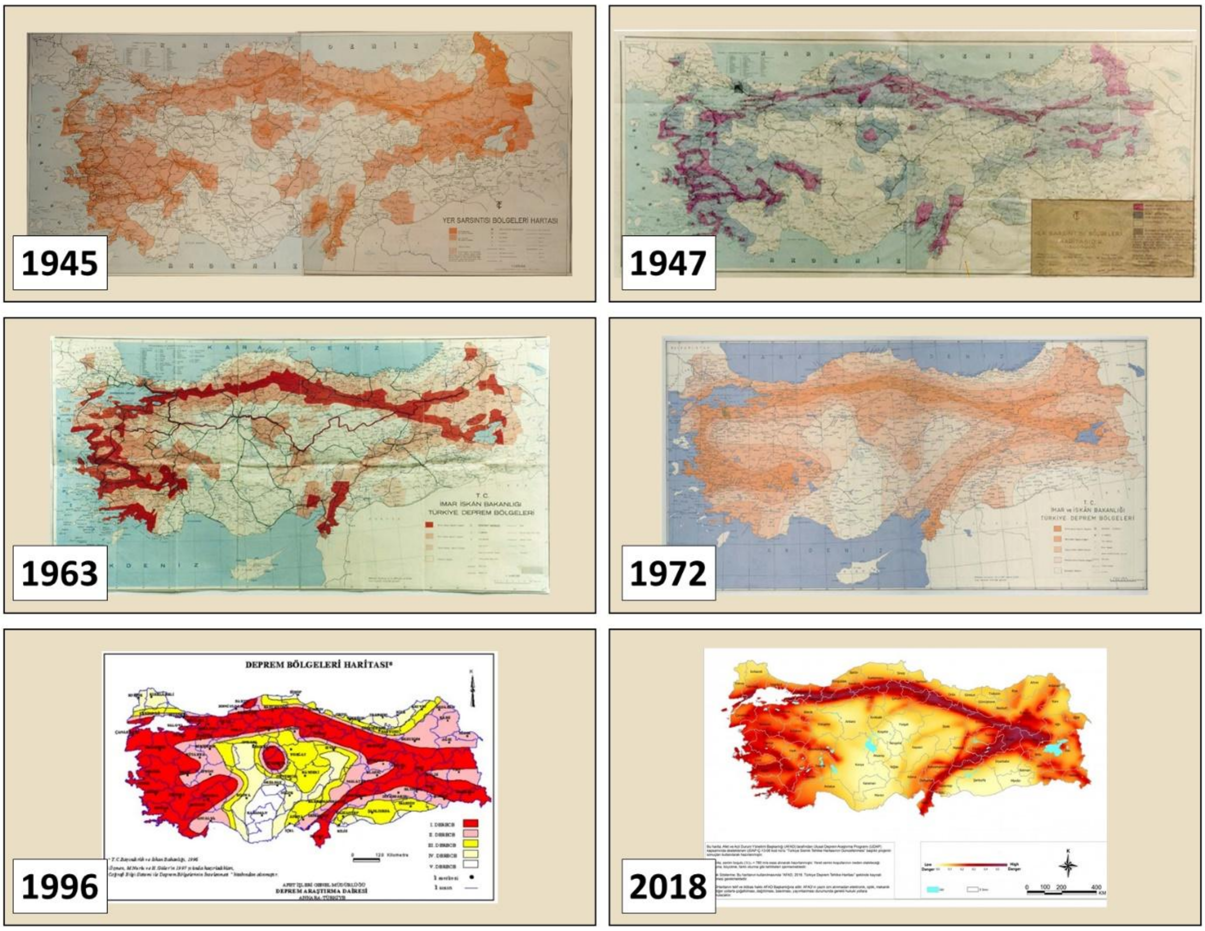


Figure 12: *Historical development of Türkiye Earthquake Hazard Maps.*

As part of the Turkish Building Earthquake Code (TBEC, 2018), a site-specific probabilistic seismic hazard map providing continuous spectral acceleration values replaced the previous discrete four-zone hazard classification, which, although also informed by probabilistic seismic hazard analysis, assigned uniform hazard levels across broad zones. Four distinct earthquake levels are included in the most recent Turkish seismic code and hazard map. These earthquake levels from DD-1 to DD-4 correspond to specific exceedance probabilities in 50 years (2%, 10%, 50%, and 68%) and return periods (2475, 475, 72, and 43 years), respectively. The standard design earthquake (SDE) corresponds to DD-2 level, against which buildings are verified for the life-safety performance objective. The maximum considered earthquake (MCE) is represented by DD-1 level and is used for collapse-prevention verification, for the design of seismically isolated structures, and for near-fault assessment. For all earthquake levels, the Turkish Seismic Hazard Map provides PGA, PGV and 5%-damped pseudo-spectral acceleration (PSA) values at periods of 0.2 s and 1.0 s for reference rock (V_{S30} = 760 m/s) at geo-referenced grid coordinates, allowing users to retrieve site-specific hazard parameters for any location.

The recent probabilistic-based hazard map also provides a user-friendly web interface through which a brief report consisting of horizontal and vertical elastic design spectra which can be generated based on the selected seismic ground motion level and local soil class (ZA-ZF, representing stiff to soft soils). However, only registered users[2] of the Türkiye e-Devlet (e-Government) Gateway are able to access this interface of the Turkish Earthquake Hazard Map (2018).

[2] Access to e-Devlet requires a Turkish identification number, available to citizens and registered foreign residents.

Given that the DD2 level is widely used as the seismic load level in residential projects, the PGA distribution for the Marmara region under DD2 conditions is illustrated in Figure 13. The map shows increasing PGA levels with a colour gradient from white to dark red. The distribution of PGA values along the Marmara coast for the DD-2 earthquake level indicates higher values along the southern coast of Istanbul (~0.4-0.5 g) compared to the southern Marmara region (Balıkesir, Çanakkale, and Bursa), where values range from approximately 0.3 to 0.4 g. Nevertheless, PGA values tend to be higher in the EW direction than in the NS direction according to the Turkish Seismic Hazard Map. Particularly along the north western coast of the Marmara Sea (Tekirdağ coastline), PGA values exceed 0.6 g whereas PGAs along the eastern shorelines generally range between 0.5 and 0.6 g.

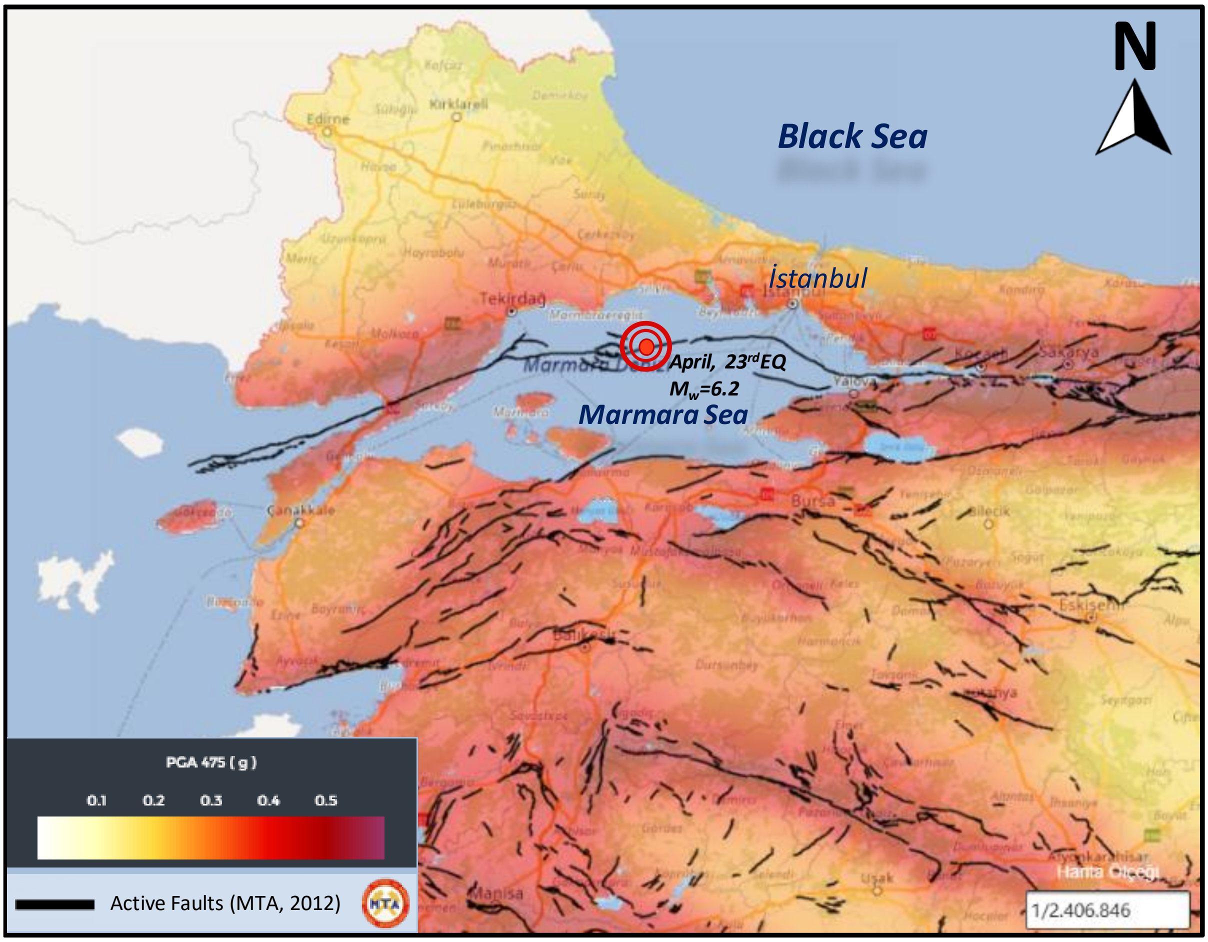


Figure 13: *Spatial distribution of peak ground accelerations (PGAs) for reference rock (V_{S30} = 760 m/s) for the standard design earthquake (SDE – DD-2 level; 10% probability of exceedance in 50 years) based on the 2018 Türkiye Seismic Hazard Map. Red concentric circle refers to M_W 6.2 Marmara Sea earthquake, 2025.*

Considering the proximity to the epicentre particularly along the southern coasts of Istanbul and the observations from Figure 10 and Figure 11, which corroborate the stronger ground motion effects in this region in terms of PGA, the recorded PGA and PGV values at the stations with the highest ground motions are compared against the code-prescribed DD-1 and DD-2 design levels at those locations (Table 2). The largest PGA and PGV values observed during the M_W6.2 Marmara Sea earthquake remain below the DD-2 level standard design earthquake at all stations. Moreover, in line with the results discussed above, Station 3429, which is the nearest station to the epicentre, has lower DD-2 level design PGA and PGV values compared to Station 3415. The discussion of spectral accelerations for different structural periods is presented in a subsequent section.

Table 2: *Peak ground accelerations (PGAs) and peak ground velocities (PGVs) at Stations 3415, 3431, 3429 and 3428 relative to the values obtained from the Türkiye Seismic Hazard Map for the DD-2 design level (standard design earthquake; 10% probability of exceedance in 50 years) and the DD-1 design level (maximum considered earthquake; 2% probability of exceedance in 50 years)*

Station Code	**3415 (*R_{EPI}=48.7 km*)**		**3431 (*R_{EPI}=55.3km*)**		**3429 (*R_{EPI}=25.87km*)**		**3428 (*R_{EPI}=44.72km*)**	
Component	**DD-2**	**DD-1**	**DD-2**	**DD-1**	**DD-2**	**DD-1**	**DD-2**	**DD-1**
Peak Ground Acceleration, PGA (cm/s²)	408.09	684.74	267.81	480.69	310.00	560.15	501.30	837.77
$\frac{PGA_{max}}{PGA_{DD-2\ or DD-1}}$ (%)	52%	31%	61%	34%	34%	19%	20%	12%
Peak Ground Velocity, PGV (cm/s)	25.52	43.94	16.97	29.34	20.75	37.57	31.05	53.43
$\frac{PGV_{max}}{PGV_{DD-2\ or DD-1}}$ (%)	31%	18%	17%	10%	34%	19%	46%	27%

2.5.4 Comparison with Ground Motion Prediction Equations

For the Mw 6.2 Marmara Sea earthquake, the recorded PGA, PGV, and 5% damped spectral accelerations at structural period T = 1.0 s are systematically compared with the estimates obtained from the ground motion prediction equation (GMPE) developed by Kale et al. (2015), hereafter denoted as KAAH15. This GMPE was developed for shallow crustal earthquakes (depths ≤ 35 km) in Türkiye and Iran using 1,198 accelerograms from the Earthquake Model of the Middle East Region (EMME) project database, covering a magnitude range of 4 ≤ M_W ≤ 8 and Joyner–Boore distances up to 200 km (Kale et al., 2015). It was selected for this comparison because it incorporates Türkiye-specific regression coefficients and allows selection of faulting type and regional parameters, making it the most regionally appropriate model available. The purpose of the comparison is twofold: to evaluate the attenuation characteristics of the observed ground motion parameters as a function of epicentral distance (R_{EPI}) and local soil conditions (V_{S30}), and to assess the predictive performance of this GMPE against a well-recorded moderate event on the North Anatolian Fault Zone – providing an empirical benchmark for its continued use in probabilistic seismic hazard analysis in the Marmara region. The distance scaling relationships of the KAAH15 model incorporate representative mean V_{S30} values for each soil class (268 m/s for ZD&ZE, 475 m/s for ZC, and 1049 m/s for ZA&ZB), thereby accounting for site condition effects. Considering that the event took place along the strike-slip dominated North Anatolian Fault Zone, the strike-slip faulting mechanism is incorporated into the analysis framework. Moreover, regression coefficients obtained from Türkiye-based earthquake datasets are preferred for regional parameterisation, as their use is expected to enhance the estimation capability of the ground motion model for the Mw 6.2 Marmara Sea earthquake.

The analysis involves comparing the median, together with the median ± σ and median ±2σ estimates of KAAH15 against the geometric mean of the ground motion parameters as illustrated in Figure 14. For all soil classes, the geometric mean of the actual PGAs remains within the median ± 2σ prediction interval. However, it should be emphasized that the majority of the PGA values tend to be higher than the median predictions. In the comparison of the geometric mean of PGV, a similar trend is identified; however, the data appear more scattered around the median values and are generally distributed within the median ± 2σ range. This effect is more pronounced for soil classes ZD and ZE with a few exceedances of the median

+ 2σ bound. A similar tendency is also evident in the spectral accelerations (SAs) evaluated at a structural period of T = 1.0 s.

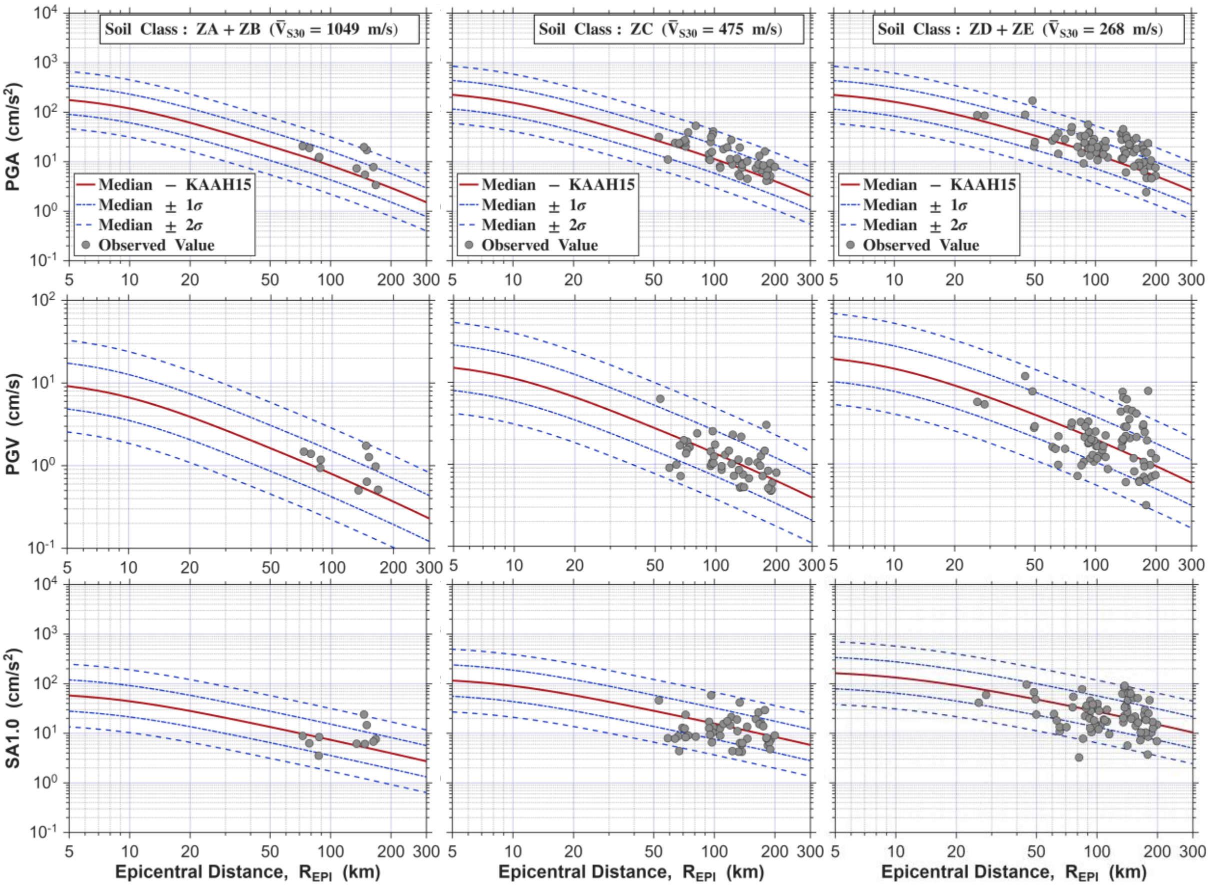


Figure 14: *Comparison of the geometric mean of PGA, PGV, and SA (T=1.0 s; ξ=5%) with ground motion prediction equation of Kale et al., 2015 (KAAH15) for the Mw 6.2 Marmara Sea earthquake.*

The evaluations based on ground motions recorded by the Istanbul Earthquake Rapid Response System (IERRS) network can be found in the event report published by the Earthquake Engineering Department of the Kandilli Observatory and Earthquake Research Institute (KOERI), Boğaziçi University (Hancılar et al., 2025). Comparative analyses of ground motion models for PGA, PGV, and spectral accelerations were also performed using four established GMPEs: BSSA14 (Boore et al., 2014), ASB14 (Akkar et al., 2014), KAAH15 (Kale et al., 2015), and CB14 (Campbell and Bozorgnia, 2014), considering only IERRS data. The results corroborate the tendency of KAAH15 median predictions to underestimate ground motion parameters, particularly PGA, while showing that the majority of the observed data fall within the median ± 2σ range with only limited local exceedances observed.

2.6 Tsunami

The 23 April 2025 earthquake generated a minor tsunami in the Marmara Sea, recorded at several tide gauge stations. Maximum observed wave heights were: 6 cm at Erdek, 4 cm at Esenköy, and 3 cm at Silivri (AFAD, 2025; Erdik et al., 2025). These values are consistent with the moderate magnitude of the event and the confined geometry of the Marmara Sea, and caused no damage or injury. Tsunami warnings were not issued.

Although the 2025 tsunami was negligible, its occurrence confirms that the North Anatolian Fault's Marmara segment is capable of generating co-seismic seafloor displacement sufficient to produce measurable sea surface perturbations. Hébert et al. (2005) modelled tsunami propagation from fault rupture scenarios in the Marmara Sea and estimated wave heights of

3–4 m at Istanbul's European coastline under worst-case scenarios, with the most severely affected areas concentrated along the shores of the Historic Peninsula and the Bakırköy–Küçükçekmece coastal strip. The 2025 event provides a minor empirical calibration point for these models. The coastal European-side districts – which also generated the highest building damage report concentrations in this event – would therefore be exposed to both strong ground motion and tsunami inundation in the major anticipated rupture, a compounding of hazards that current urban planning and emergency response frameworks do not appear to explicitly address.

2.7 Conclusions

A Mw 6.2 earthquake took place on April 23rd of 2025 at a shallow depth of 7 km along the western (Kumburgaz) segment of the northern branch of the right-lateral strike-slip North Anatolian Fault Zone (NAFZ) beneath the Sea of Marmara. The NAFZ governs seismicity in the Sea of Marmara region and has previously exhibited a westward migration of large earthquakes, a pattern that persisted until roughly the last 15 years. However, the spatial distribution of aftershocks following the 2025 Marmara Sea earthquake, along with the 2019 events, points out a possible eastward migration of seismic activity toward the southern vicinity of Istanbul.

Within an epicentral distance of 200 km, a total of 212 strong ground motion stations from multiple networks provide relatively dense coverage of the region with the majority deployed on ZC and ZD soil classes (loose to medium sand and soft to stiff clay). The highest horizontal PGA (~211.73 cm/s² - 0.22 g) is observed in the NS component at station 3415 (ZD soil), which also shows the largest geometric mean (~171.2 cm/s² - 0.17 g). Other ground motion parameters (PGV, Ia, RMS and CAV) consistently attain their maximum values at this station. Interestingly, several stations closer to the epicentre, despite having similar soil conditions, exhibit lower amplitudes than station 3415, located 48.7 km away. Also, PGA and PGV values recorded during the 2025 Marmara Sea earthquake are found to be lower than the DD-2 design values (10% probability of exceedance in 50 years), ranging from approximately 20% to 52% of code DD-2 levels, provided by the Turkish Earthquake Hazard Map, 2018. Additionally, a systematic comparison of PGA, PGV, and 5% damped spectral accelerations at T = 1.0 s with the predictions of the GMPE proposed by Kale et al. (2015) indicates that the geometric mean of the observed PGA values falls within the median ± 2σ prediction interval. However, PGA exhibits a slight overestimation tendency by the GMPE for all soil classes.

3 The Built Environment: Seismic Code Evolution, Risk Assessments and Hidden Vulnerabilities

Chapter summary in plain terms

This chapter explains why Istanbul's building stock carries the earthquake risk it does, and why that risk is not simply a function of what the building codes say. Turkish seismic regulation has improved substantially since 1940, with 1975 and 1999 as the two critical thresholds: the 1975 code was the first to introduce structural ductility requirements, while the 1999 Kocaeli earthquake prompted a fundamental overhaul culminating in the probabilistic TBEC 2018. However, approximately 70% of Istanbul's buildings predate the post-1999 transition, and a substantial proportion of the pre-1975 stock – designed with no ductility requirements, low concrete strengths and inadequate detailing – represents a categorically higher risk cohort. Scenario loss studies conducted since 2002 (IMM/JICA 2002; Erdik et al., 2003; IMM/KOERI, 2019) consistently identify the same seven southern European-side districts as highest-risk: Fatih, Küçükçekmece, Bağcılar, Bahçelievler, Zeytinburnu, Avcılar and Esenyurt. The 2025 earthquake confirmed this pattern under real, sub-design loading conditions. Beyond the regulatory record, the chapter documents hidden vulnerabilities that extend this risk to nominally modern buildings: construction quality deficiencies, a third-party inspection system structurally compromised by its fee structure and client relationships, informal post-occupancy structural interventions, and the repeated legalisation of non-compliant buildings through construction amnesties. Approximately 317,000 buildings in Istanbul have been legalised through such amnesties, of which roughly 90,000 are considered at serious collapse risk. The 2025 post-earthquake inspections in Küçükçekmece – where RC columns were found to contain marine shell fragments, indicating concrete made from unwashed beach sand – illustrate that this is not a historical problem: the same implementation failures documented after the 2023 Kahramanmaraş sequence are detectable in Istanbul under moderate loading.

3.1 Introduction

Today, Istanbul is a megacity with a population of approximately 15.6 million (TÜİK, 2026), largely concentrated within a dense urban environment dominated by mid- and high-rise reinforced concrete (RC) building typologies. The southern shores are located approximately 20 km from the Marmara segments of the North Anatolian Fault. In this recognised seismic gap, the last major ruptures occurred during the eighteenth century, following the historical earthquakes of 1509 and 1766 (Section §2.3). Since then, the segment has accumulated centuries of tectonic strain. Numerous studies have consequently estimated a substantial probability of a future major earthquake, M ≥ 7, occurring along the Marmara segment (Figure 16), commonly ranging between approximately 35 and 70% over 30-year forecast windows, depending on the modelling approach and time window considered (Parsons et al., 2000; Parsons, 2004; Murru et al., 2016).

In the high-seismicity context of Türkiye, and particularly of Istanbul, the earthquake performance and relevant recognisable risk in RC buildings are first closely linked to the regulatory environment under which the built environment has evolved. Therefore, seismic codes **and their implementation** constitute a fundamental framework for interpreting the vulnerability of Istanbul's building stock from a structural engineering and design perspective.

Accordingly, the following section first examines the historical development of seismic codes and major earthquakes in Türkiye, particularly in relation to the evolution of Istanbul's macroform and RC building stock.

3.2 Seismic Code Evolution in the Context of Istanbul

In Türkiye, two parallel regulatory streams govern RC construction: standards for the reinforced concrete design (TS-500, 2000) and Turkish Earthquake Codes (TEC, 1940-2018, namely the Specifications for Structures to be Built in Disaster Areas, which were subsequently revised under various titles, including Turkish Building Earthquake Code of 2018). Similar to many other earthquake-prone countries, major earthquake disasters in Türkiye frequently initiated revisions to codes and other building regulatory requirements and incentivised improvements in engineering practice. Throughout successive TEC editions prior to TBEC 2018, masonry infill walls were treated as non-structural elements, excluded from structural models and without provisions addressing detrimental infill–frame interaction effects such as soft-storey mechanisms at open ground floors or short-column failure induced by partial-height infilling.

In the case of Istanbul, this major earthquake event as trigger for updated regulation relationship is particularly critical as a substantial proportion of the existing building stock was constructed during periods of intense urban growth, often under earlier generations of seismic regulations and within rapidly transforming urban and political conditions (Figure 15). Figure 16 maps and chronologically illustrates the historical macroform expansion of Istanbul in relation to key earthquakes and seismic regulation in Türkiye and population growth in Istanbul.

Figure 15: *Contrasting residential building typologies, European side of Istanbul. (a) Pre-1994 low-rise RC frame stock representative of the vulnerable building inventory; Ataköy, Bakırköy (photographs 1 and 3: B. Karagöz, 2025); Bağcılar (photograph 2: M. Flesier, CC BY-SA 4.0; photograph 4: İ. Dinç, CC BY-SA 3.0). (b) Post-2000 construction, Ataköy, Bakırköy (B. Karagöz, 2025).*

It should be noted that the macroform expansion periods presented in Figure 16 (1920-1955, 1955-1975, 1975-1994, and 1994-2014) were classified according to the temporal resolution permitted by the available spatial data and interpreted in relation to urbanisation and major phases of seismic code development (based on TEC, 1940-2018; Sezen et al., 2000; Sezen et al., 2003; İlki and Celep, 2012) where possible. These periods should therefore be understood as a broad analytical lens rather than a direct representation of the age or regulatory classification of individual buildings. In practice, many areas that experienced early urban expansion also contain substantial later-period development constructed under newer generations of seismic regulations.

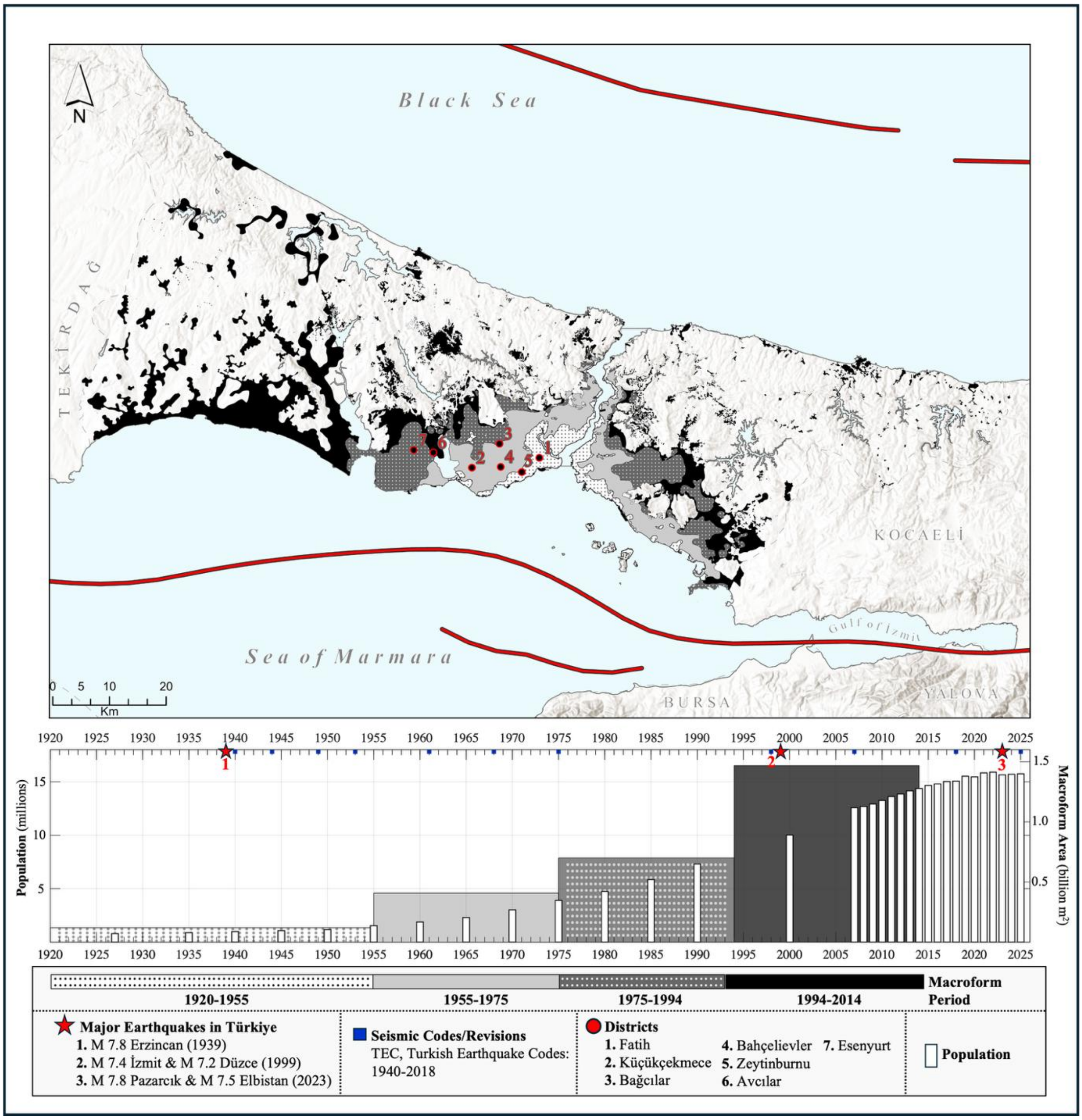


***Figure 16: (Top)** Historical macroform expansion of Istanbul (Macroform boundaries for 1920–1985 were compiled and digitised from Döker, 2012, and IMM, 2009, as reproduced by Güzel and Turer Baskaya, 2020; post-1985 boundaries were produced based on Landsat-5 TM and Landsat-8 OLI), shown together with the active segments of the North Anatolian Fault within the Sea of Marmara (Basili et al., 2020) and the high-risk districts, 1-7, identified in previous earthquake risk assessments. **(Bottom)** Periodised macroform expansion of Istanbul in relation to population growth (TÜİK, 2026), the chronological evolution of Turkish seismic building regulations (compiled and refined from TEC, 1940–2018; Sezen et al., 2000), and key major earthquakes that shaped Türkiye's seismic regulatory framework. Data sources: Pre-1985 macroform boundaries adapted from Döker (2012, Istanbul University), Kubat and Hazar (2012), and Istanbul Metropolitan Municipality planning documents. Post-1985 macroform boundaries derived in this study through classification and visual interpretation of historical satellite imagery; built-up areas were digitised for selected years to represent the spatial development of Istanbul's urban macroform. Active fault segments: Basili et al. (2020). Population data: TÜİK (2026). Seismic regulation timeline: TEC (1940–2018); Sezen et al. (2000).*

Regulatory response began in the aftermath of the devastating 1939 M 7.8 Erzincan earthquake, which caused approximately 33,000 fatalities and remains one of the most catastrophic earthquakes in the nation's history (EM-DAT, 2026). The first earthquake regulation, *Zelzele Mıntıkalarında Yapılacak İnşaata ait İtalyan Yapı Talimatnamesi*, was issued in 1940, drawing substantially on Italian seismic codes of the period. By present-day standards, this initial code was rudimentary, providing basic stipulations for earthquake force calculations but establishing no meaningful ductility requirements or detailing provisions for reinforced concrete. The first macro-level seismic zonation map for Türkiye and the following revisions were also published in this decade, as further discussed in Section §2.5.3 and Figure 12. The first regulated decades (1920-1955) corresponded to an early macroform stage of Istanbul, with a built-up area of approximately 0.12 billion m² and a population below one million.

The 1953 revision introduced load combinations incorporating earthquake effects but was still lacking RC detailing requirements. The 1961 earthquake code revision refined the seismic force calculation method, and the hazard map revision in 1963 (Figure 12) provided updated macro-zonation. The 1968 code represented a further improvement. However, the critical point is that none of these codes incorporated ductile detailing requirements (Sezen et al., 2003; İlki and Celep, 2012). Istanbul's building stock was still predominantly composed of masonry structures. The proliferation of RC frame construction accelerated from the 1960s onwards.

In the period of 1955-1975, Istanbul's urban expansion accelerated significantly, with the city spreading westwards across the European mainland and, on the Asian side, primarily along the southern coastline and the Bosphorus corridor (Figure 16). The city's macroform expanded approximately fourfold, reaching nearly 0.4 billion m². Buildings of this period arguably constitute one of the most vulnerable segments of Istanbul's existing building stock, not only because of the limitations of the regulatory framework, but also due to rapid and often informal urbanisation processes between 1960 and 1980. Intense rural-to-urban migration that transformed Istanbul (Karpat, 2004) from a city of approximately 1.5 million inhabitants in 1960 to more than 4.7 million by 1980 (Figure 16). A significant proportion of this construction occurred informally, as *gecekondu* (informal) settlements, entirely vernacular and outside any code-based design and construction. The long-term implications of such building stocks within the Türkiye context, particularly in light of lessons from the 2023 earthquakes and construction amnesties, are discussed further in Section §3.3.

The RC structures of these two eras, which still constitute a substantial proportion of Istanbul's current building stock, particularly in inner-city districts that urbanised rapidly during the 1960s and 1970s were typically designed with low concrete strength (often below C20 in practice), smooth reinforcing bars (rather than ribbed bars), inadequate transverse reinforcement at beam-column joints, insufficient confinement of column end regions, no strong beam/weak column principle, no shear design incorporating overstrength, 90-degree hooks on stirrups (rather than 135-degree hooks for effective confinement), short lap splice lengths, frequently located at column base sections where plastic hinge formation is expected.

The 1975 seismic code, *Afet Bölgelerinde Yapılacak Yapılar Hakkında Yönetmelik*, represented the first major modernisation of earthquake design regulations in Türkiye for its time. The code introduced the concept of structural ductility levels and provided more comprehensive procedures for seismic force calculations. Accordingly, many earthquake risk assessment frameworks in Türkiye treat 1975 as a critical threshold, commonly classifying pre-1975 construction as effectively non-code-compliant or highly deficient by modern seismic design standards.

The following period, 1975-1994, also corresponded to another phase of metropolitan expansion. As illustrated in Figure 16, the city's macroform expanded from approximately 0.4 billion m² to nearly 0.7 billion m², while the population increased from approximately 3.9 million in 1975 to more than 7.3 million by 1990. Characteristics of this period had been peripheral urbanisation, reinforced concrete frame apartment-block construction, predominantly moment-resisting frames with unreinforced masonry infill walls, and the first construction amnesty in the 1980s.

The 1998 earthquake code revision represented another attempt to bring Turkish seismic design practice into closer alignment with modern performance expectations. The code introduced more strict ductile detailing requirements for RC frames, improving confinement requirements for columns and beam-column joints. Requirements for capacity design principles, updated seismic force reduction factors tied to structural ductility levels, and improved provisions for structural irregularity were also incorporated. However, this code came into force less than two years before the catastrophic 1999 İzmit/Kocaeli (M 7.4) and Düzce (M 7.2) earthquakes, which together caused approximately 18,000 fatalities (EM-DAT, 2026). The majority of buildings that collapsed or suffered severe damage during the 1999 earthquakes had been constructed under earlier and less stringent seismic regulations. Nevertheless, post-earthquake reconnaissance (D'Ayala et al., 2003) revealed that even some nominally code-compliant structures performed poorly due to implementation-related deficiencies. Building control during this period relied on municipal inspection, which was widely recognised as under-resourced relative to the pace of construction; the third-party building inspection system (*Yapı Denetim*) was not introduced until 2001, following the 1999 Kocaeli earthquake (Law 4708), and was not extended nationwide until 2011 (see §4 for a fuller discussion of implementation in the urban transformation context).

In retrospect, the 1999 events and the subsequent advances in earthquake engineering and disaster governance constituted an intermediate milestone between two defining national disasters: the 1939 Erzincan earthquake and the 2023 Kahramanmaraş earthquake sequence.

In the following decades, Turkish seismic regulations continued to evolve towards a more comprehensive and performance-focused framework. A third-party building inspection system (*yapı denetim*) was introduced in 2001 under Law 4708, replacing the earlier regime of municipal inspection. Licensed private companies (*yapı denetim kuruluşları*) were made responsible for verifying structural design and monitoring construction compliance. However, since the inspection company is contracted and paid by the building owner or developer, concerns about independence and consistency have persisted, and the quality of inspection has been uneven in practice (Kayaalp, 2025). Then, the 2007 Code, Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik, introduced several major advances in both the design of new structures and the assessment of existing buildings (TEC, 2007). Among its most significant developments were the incorporation of performance-based assessment methodologies for existing structures, refined ductile detailing requirements for reinforced concrete systems, improved criteria for identifying structural irregularities, and a more detailed soil classification framework. The code also introduced updated design spectrum formulations and refined provisions for structural irregularities, reflecting the increasing alignment of Turkish seismic design practice with contemporary international approaches. In practice, the adoption of performance-based methods was uneven: while specialist engineering firms and academic consultancies applied the new procedures, the majority of practising engineers responsible for routine building assessment continued to rely on simplified linear-elastic approaches, a capacity gap that the simplified RBTE methodology (§4.2) was partly designed to address. Provisions for seismic isolation and supplemental energy dissipation systems were introduced subsequently under the 2018 code (TBEC 2018), which for the first time brought base-isolated structures within the scope of the national seismic design framework. The 2007 code was the first Turkish seismic regulation to include a codified methodology for evaluating the expected seismic performance of existing buildings (Chapter 7 of TEC 2007), providing an essential technical basis for the urban transformation and building retrofit programmes that would follow. The 2018 code (TBEC 2018) subsequently expanded and refined these provisions, incorporating nonlinear assessment procedures and updated acceptance criteria.

The 1994-2014 period represented the most extensive phase of Istanbul's macroform expansion. During this period, the city's built-up area more than doubled, increasing from approximately 0.7 billion m² to nearly 1.5 billion m², while the population grew from around 7.3 million in 1990 to more than 14 million by 2014. Spatially, this phase was characterised by large-scale peripheral expansion towards the western coastal corridor on the European side and the eastern mainland on the Anatolian side, alongside the consolidation of urban zones and the emergence of extensive mass-housing and high-rise residential developments. Figure 16 also illustrates the increasing fragmentation and outward clustering of urban development towards the northern parts of the city, where new residential areas emerged beyond the historically linear coastal, both along the Sea of Marmara and Bosphorus, urbanisation pattern.

The 2018 code, *Turkish Building Earthquake Code*, which came into force on 1 January 2019, represent the most comprehensive code to date. The previous system of discrete macro-level seismic zones was replaced by a probabilistic hazard map providing spectral acceleration parameters, enabling geographic coordinate-based seismic demand parameters (Figure 12). In parallel, TBEC 2018 defined four ground motion levels with return periods of 43, 72, 475, and 2,475 years (*deprem düzeyi*, *DD*), enabling performance assessment/verification at different hazard levels. While the previous procedure remains force-based, explicit performance targets are defined for different ground motion levels. Service level performance is assessed by force-based analysis, while collapse prevention performance requires performance-based procedures involving nonlinear time history analysis. It also included provisions for seismic isolation and supplemental energy dissipation systems.

An important aspect in interpreting Istanbul's earthquake risk is that, at the time of writing this report, a substantial proportion of the existing building stock – approximately 70% as of 2019 – predates the post-1999 regulatory transition (IMM and KOERI, 2019). Although seismic regulations in Türkiye have progressively evolved towards increasingly sophisticated and internationally comparable standards, these advancements are only meaningful insofar as they are properly implemented, as discussed in Section §3.3. Therefore, earthquake risk in Istanbul should not be interpreted solely without the long-term accumulation of hidden vulnerabilities within the built environment, as the 2023 earthquake sequence demonstrated.

3.3 Earthquake Risk Analyses for Istanbul: A Summary

Following the 1999 events, the first comprehensive loss estimation study was conducted by the Istanbul Metropolitan Municipality (IMM) in partnership with the Japan International Cooperation Agency (JICA) in 2002 (IMM and JICA, 2002). The study analysed approximately 725,000 buildings and a population of about 9 million (corresponding to 3.04 million households). For M 7.5 & 7.7 scenarios, it estimated 50,000-60,000 severely damaged buildings, 73,000-87,000 fatalities, around 50 million tonnes of debris, and material losses of approximately USD 40 billion. These estimates placed Istanbul among the most risk-prone megacities.

Boğaziçi University's Kandilli Observatory and Earthquake Research Institute (KOERI) also developed earthquake risk assessment studies for the Istanbul metropolitan area since the early 2000s. Erdik et al. (2003) conducted one of the earliest comprehensive scenario-based earthquake risk assessments for Istanbul. Using a M 7.5 (credible worst-case) Marmara earthquake scenario, the study estimated that approximately 35,000-40,000 buildings could suffer complete damage, around 70,000 buildings extensive damage, and nearly 200,000 buildings moderate damage. Fatality estimates ranged between 30,000-50,000 depending on the methodology adopted, while hundreds of thousands of households were projected to require temporary housing. Importantly, the study framed Istanbul's earthquake risk not solely as a consequence of structural and geotechnical vulnerability, but also as the product of rapid urbanisation, faulty land-use planning, inadequate infrastructure, and deficiencies in construction practice.

The 2003 Earthquake Master Plan for Istanbul (EMPI), commissioned by IMM and prepared by Boğaziçi University, Istanbul Technical University, Middle East Technical University, and Yıldız Technical University, built upon earlier hazard and damage assessments but shifted the emphasis towards mitigation planning. EMPI identified priorities for urban transformation, infrastructure retrofitting, emergency response, and institutional preparedness.

The most recent comprehensive update was the 2019 Istanbul Province Possible Earthquake Loss Estimates Update Project, prepared by IMM and KOERI, Boğaziçi University (IMM and KOERI, 2019). This study analysed 1,166,330 buildings using updated inventory data, introducing also analytical fragility functions. For a M 7.5 scenario, it estimated that approximately 57% of buildings would remain undamaged, while 26% would experience light damage, 13% moderate damage, 3% heavy damage, and 1% very heavy damage or collapse. Approximately 194,000 buildings were estimated to sustain moderate or greater damage. In addition to injuries exceeding 100,000 in both daytime and nighttime scenarios, estimated fatalities were approximately 14,150 for the nighttime scenario and 12,400 for the daytime scenario. The same study also projected substantial disruption to water infrastructure, road networks, and post-earthquake shelter capacity.

In these studies, as illustrated in Figure 16, several southern, mostly coastal districts repeatedly emerge as high-risk areas, including Fatih, Küçükçekmece, Bağcılar, Bahçelievler, Zeytinburnu, Avcılar, and Esenyurt. These districts combine different forms of vulnerability, such as ageing masonry and early pre-1975-code RC stock, dense residential developments, unfavourable soil conditions, rapid urbanisation, and/or high population exposure.

All the estimates should be interpreted within their methodological and temporal context. The comparison between these approaches is also important because different models, ground-motion representations, and assumptions about building response can produce different loss estimates.

Furthermore, such estimates again remain sensitive to uncertain assumptions regarding construction quality, code compliance, post-occupancy interventions, and the actual structural condition of existing buildings.

3.4 Hidden Determinants of Earthquake Risk in Istanbul

Field evidence from the catastrophic 2023 Türkiye earthquake sequence (Aktas et al., 2024) demonstrated the significance of other hidden, accumulated risk determinants in Türkiye's built environment. These vulnerabilities emerge across multiple phases of the building life cycle, including design, construction, and post-occupancy, many of which often reflect broader systemic deficiencies. For instance, as highlighted by İlki and Celep (2012), the poor seismic performance of many existing buildings in Türkiye is largely associated not with the inherent inadequacy of the seismic codes themselves, but with systemic deficiencies across the building delivery chain: inadequate structural design (including non-engineered and informally engineered construction), poor construction quality in materials and workmanship, insufficient independence and rigour in the inspection regime, and – in both formal and informal construction – the absence of competent professional oversight at key stages of the process.

Similarly, in the post-occupancy phase, additional undocumented vulnerabilities are frequently created through unregulated and informal structural interventions, particularly in very common mixed-use RC buildings where ground floors are often modified for commercial purposes. The removal of, or intervention in, load-bearing structural elements, commonly due to the creation of larger retail spaces at the ground level, is a widespread problem and has repeatedly led to instant collapse cases, including in buildings originally designed under relatively modern seismic codes (So et al., 2024).

These arguments are of direct relevance to Istanbul. If code-compliance failures are systemic and extend to post-2007 and even post-2018 construction, then the binary 'risky/not risky' designation produced by individual building assessments under the RBTE framework (§4.2) may give false assurance, while city-scale probabilistic risk assessments – which typically incorporate construction-quality variability through fragility function parameters – are better positioned to capture this uncertainty, provided the underlying assumptions about the distribution of construction quality remain valid. In this respect, the effectiveness of seismic regulations and scientific risk assessments is ultimately constrained by the conditions shaping design, construction, inspection, and occupancy practices at a given time.

Despite this significant gap between regulatory intent and built reality, such deficiencies have periodically been legalised and institutionalised through the practice of *imar barışı* or *imar affı* (construction amnesties), most recently in 2018. Construction amnesties are legal mechanisms that retroactively legitimise buildings constructed without permits or in violation of earthquake-resistant building regulations. While construction amnesties in some contexts can serve a positive social function – extending legal tenure and property rights to low-income homeowners who would otherwise remain in informal and unprotected status – in the Turkish case their cumulative effect has been to entrench seismically vulnerable construction within the formal building stock, shielding it from the regulatory scrutiny that might otherwise have triggered assessment or retrofit. The concept was first formally codified in 1984 under the military government and has since been implemented repeatedly, often in close proximity to election periods, as comprehensively discussed by Woo et al. (2024). The cumulative effect has been substantial. Following the 2023 earthquakes, 144,556 buildings in Kahramanmaraş and approximately 205,000 buildings in Hatay were reported to have benefited from construction amnesties (TMMOB, 2023). Similarly, according to a statement by the Mayor of Istanbul cited by Woo et al. (2024), approximately 317,000 buildings in Istanbul had been legalised through construction amnesties, of which nearly 90,000 were considered to face a serious collapse risk in the event of a major earthquake affecting the city. These figures should be read alongside the weaknesses of the inspection regime itself: although the third-party building inspection system (*yapı denetim*) introduced in 2001 was intended to ensure structural compliance, inspection firms have in practice often operated with limited independence from the construction companies whose work they are tasked with verifying, with low fee structures that incentivise cursory paperwork-based sign-off over rigorous site inspection and testing (§3.2). The absence of a mandatory professional licensing and continuing-competence framework for structural engineers in Türkiye compounds this problem.

Earthquake risk governance in Istanbul requires coordination across several institutional scales. Central government institutions play a major role through AFAD, the Ministry of Environment, Urbanisation and Climate Change, and TOKİ, the Housing Development Administration of the Republic of Türkiye (*Toplu Konut İdaresi*), for mass housing, while the IMM and the 39 district municipalities are responsible for local implementations, building-related administrative processes, urban planning, and management of some infrastructure elements. The political and administrative tension between the central government and the IMM may constrain coordinated risk reduction efforts.

3.5 Discussion and Conclusions

The three threads of this chapter – seismic code evolution, scenario loss estimates, and hidden determinants – converge on a single conclusion: Istanbul's earthquake risk cannot be interpreted solely through seismic hazard or through the evolution of seismic regulations. Instead, the current risk profile of the city has emerged through the accumulated gap between regulatory frameworks and built reality, compounded over decades of rapid urban growth.

The regulatory record is one of genuine progress. From the early rudimentary codes following the 1939 Erzincan earthquake to the performance-oriented framework of TBEC 2018, Turkish seismic regulation has progressively converged on international standards. That progress is real and should not be discounted.

What the regulatory record cannot fully account for is the building stock that pre-dates it. As of 2019, approximately 70% of Istanbul's buildings were constructed before the post-1999 regulatory transition (IMM and KOERI, 2019). A substantial proportion of these – particularly the RC frame stock built during the rapid urbanisation of the 1960s and 1970s – was designed under codes with no capacity design provisions, no efficient ductile detailing requirements, and was constructed with low concrete strengths, smooth reinforcing bars, inadequate confinement and 90-degree stirrup hooks. Evidence from large-scale assessment programmes confirms that implementation quality during this period was as problematic as the code limitations themselves: the ISMEP project, which assessed and retrofitted thousands of public buildings from 2006 onwards, consistently found that actual construction quality fell below even the modest requirements of the codes in force at the time of construction, with deficiencies in concrete grade, reinforcement detailing and joint confinement common across the assessed stock.

The earthquake risk assessments reviewed in this chapter consistently indicate that the consequences of a major earthquake could be severe, despite differences in methodology, exposure data, hazard representation and temporal context. The scenario loss estimates – 14,000 to 87,000 fatalities depending on methodology and scenario assumptions – represent not a precise prediction but a range of plausible outcomes for a population living in proximity to an unruptured fault segment for two and a half centuries. The IMM/JICA (2002) and IMM/KOERI (2019) studies identify the same southern districts – Fatih, Küçükçekmece, Bağcılar, Bahçelievler, Zeytinburnu, Avcılar and Esenyurt – as among the highest-risk areas in the city. These are not abstract model outputs. They correspond closely to the districts generating the highest building damage report concentrations in the 23 April 2025 event, under recorded ground motions that remained well below DD-2 design levels. The correspondence is not coincidental: it reflects the same underlying vulnerability confirmed by independent evidence streams.

The hidden determinants documented in Section §3.4 are arguably the most troubling finding. Construction quality deficiencies are well documented across all periods of Istanbul's building stock: the pre-1999 stock suffers from both code limitations and poor implementation, while the post-1999 stock benefits from substantially better codes but has not consistently achieved the corresponding improvement in construction quality in practice. If code-compliance failures extend systematically to post-2007 and post-2018 construction – through structural design and construction quality deficiencies, informal structural interventions, and the retrospective legitimisation of non-compliant buildings through repeated amnesties – then the 30% of Istanbul's stock nominally built under modern codes may offer less protection than the regulatory record implies. The 2023 Kahramanmaraş sequence demonstrated this at catastrophic scale. The 2025 event offers a local example: following the earthquake, structural inspections in Küçükçekmece documented RC columns in which the concrete aggregate contained marine shell fragments ('mussel-shell columns'), indicating the use of unwashed beach sand or marine-sourced aggregate – a fundamental material quality failure that renders the concrete porous, weak and non-compliant with even the most basic material standards (MAR-030, MAR-037, MAR-057). That such deficiencies are being discovered in Istanbul under moderate seismic loading suggests the same dynamic documented in the 2023 sequence is present here. Whether it is widespread is unknown, because the inspection and accountability framework that would make it knowable has not consistently operated as intended.

The 2025 event did not discharge that risk. The evidence reviewed in this chapter, taken together with the seismological findings of Chapter 2, indicates that Istanbul's building stock will face its full design-level test with the same vulnerabilities that exist today. Türkiye's own experience demonstrates that effective seismic risk reduction of existing stock is achievable: the ISMEP programme of assessment and retrofit of public buildings – schools, hospitals, government facilities – produced measurable performance improvements, and the broadly satisfactory performance of school buildings during the 2023 Kahramanmaraş earthquake sequence has been attributed in part to the higher standards of construction oversight applied to public buildings. However, the developer-led urban transformation programme for the residential stock operates under a fundamentally different incentive structure, and its current trajectory raises questions about whether the pace of transformation is matched by the quality, accountability and equity of its outcomes (Chapter 4). Unless both the integrity and the coverage of the risk mitigation effort are substantially improved, the vulnerabilities documented in this chapter will persist into the next major seismic event.

Rather than representing a static or purely engineering-defined condition, earthquake risk in Istanbul emerges as a historically accumulated and systematically reproduced urban process shaped by the interaction between earthquake hazard, rapid urbanisation, regulatory evolution, construction practice, and the broader political and social conditions that collectively define the "social contract" in Türkiye's built environment, as discussed by Aktas et al. (2024) in the aftermath of the 2023 earthquake sequence. The 2023 Kahramanmaraş sequence made this systemic character visible at catastrophic scale; the 2025 Marmara Sea earthquake confirmed it, at sub-design loading, in the city most exposed to what comes next.

4 Seismic Risk Mitigation in Practice: Assessment, Retrofit and Urban Transformation

Chapter summary in plain terms

Istanbul has been carrying out a large-scale urban transformation programme since 2012, aimed at demolishing and replacing highly seismically deficient buildings. In practice, the programme overwhelmingly favours demolition and reconstruction over structural retrofit, even where retrofit would achieve equivalent seismic performance at lower cost and disruption – only approximately 10% of interventions under the programme involve retrofit. This chapter examines whether the programme is working as intended. It asks three questions: Are the right buildings being identified for intervention? Is demolish-and-rebuild always the right response, or would a strategy that also includes retrofit of selected buildings better serve the goal of citywide risk reduction? And what are the wider consequences – structural, social and environmental – of a programme operating at this scale?

The evidence suggests that the screening process used to designate buildings as at-risk is considerably less rigorous than the full assessment framework the codes provide, and that financial incentives strongly favour demolition over retrofit regardless of a building's actual structural condition. The programme's benefits are not consistently directed toward the districts that need them most. A further concern is whether the replacement buildings themselves reliably meet the seismic performance standards the programme promises: the same weaknesses in construction oversight documented for the existing stock – limited independence of inspection companies, uneven enforcement, and capacity gaps among practitioners – apply equally to new construction under the programme, and no additional design scrutiny or construction monitoring regime is applied to transformation-programme buildings beyond the standard yapı denetim process. The 2023 Kahramanmaraş earthquake sequence demonstrated that post-1999, nominally code-compliant buildings can and do fail; whether replacement buildings in Istanbul's transformation zones are performing better than the stock they replace is, at present, an open question.

The 2025 event provides the first real-world test of how the programme is changing Istanbul's vulnerability profile – and the results are mixed. The spatial signal from 2025 is unambiguous: the highest damage concentrations fell in the districts where programme activity has been lowest, confirming that the programme is operating most intensively where land values support its financial model rather than where seismic risk is greatest. The carbon costs of operating at demolition scale are substantial – new RC construction produces 300-400 kg CO_2/m², versus 20-40% of that figure for retrofit – and have not been weighed against the resilience benefit delivered. A further concern, documented from fieldwork, is that the programme's financial logic has been systematically exploited: construction companies purchase a single apartment in a pre-1999 building, commission a risk assessment confident of the outcome, and use the resulting designation to force demolition and secure the reconstruction contract – a practice the chapter describes as deprem korkutmacılığı (earthquake scaremongering). The replacement buildings produced under the programme are not subject to any additional scrutiny beyond the standard yapı denetim inspection regime that demonstrably failed in 2023; a documented case of a 2006-built Istanbul building found to have concrete strengths and detailing equivalent to pre-1975 construction illustrates the risk that the programme is replacing old deficient buildings with new ones.

The programme also raises a significant equity concern: by producing higher-value replacement buildings, it is driving gentrification across transformation zones, displacing lower-income households toward peripheral areas where seismic risk may be higher and programme activity is lower – concentrating vulnerability in the populations least served by the intervention designed to protect them.

4.1 Introduction

Türkiye's approach to seismic risk mitigation of its existing building stock has followed two distinct tracks – a publicly funded programme of assessment and retrofit for critical public infrastructure (schools, hospitals), and a developer-led programme of demolition and reconstruction for the residential stock under Law 6306. The outcomes have been markedly different, and the reasons are structural rather than technical. This chapter examines the residential programme in detail.

The regulatory framework examined in Chapter 3 establishes what level of earthquake ground shaking and other actions buildings in Istanbul should be designed and constructed for. The question this chapter addresses is different: what is actually being done about the buildings that cannot meet that standard, and is it working?

Istanbul's seismic risk mitigation effort operates primarily through the urban transformation programme established under Law No. 6306 on the Transformation of Areas Under Disaster Risk (*Afet Riski Altındaki Alanların Dönüştürülmesi Hakkında Kanun*), enacted in 2012. The programme authorises the identification and demolition of buildings designated as at-risk – whether on grounds of seismic vulnerability, completion of their economic life, or location within areas identified as hazardous due to ground conditions such as liquefaction or landslide (Article 2) – the relocation of their occupants, the reconstruction of replacement buildings to current seismic standards, and the financial support of this process through state subsidies, rent assistance and development rights. At the scale of Istanbul's risk – the IMM/KOERI (2019) scenario study estimates approximately 194,000 buildings sustaining moderate or greater damage in a Mw 7.5 event, while approximately 70% of the city's 1.6 million buildings predate the post-1999 regulatory transition – it represents one of the largest peacetime urban infrastructure programmes in the world.

In February 2026, the central government launched the *Yarısı Bizden* ('Half from Us') campaign, offering to cover 50% of the cost of urban transformation for buildings declared risky, with the programme extended to 31 December 2026 to cover all buildings designated as at-risk during 2025-2026 (ÇŞİDB, 2026). The campaign is designed to accelerate the pace of transformation by reducing the financial burden on property owners, though it operates within the same developer-led incentive structure and RBTE screening process documented in this chapter.

The programme has been promoted as the primary policy response to the seismic risk identified in the scenario loss studies reviewed in Chapter 3. The acceleration and expansion of the programme have been announced repeatedly in the aftermath of major earthquakes, most recently following the 2023 Kahramanmaraş sequence and again following the 2025 Marmara Sea earthquake. Yet its relationship to Istanbul's actual vulnerability geography, and to the question of whether demolish-and-rebuild is the most appropriate technical and policy response in every case, has received limited critical examination. This chapter addresses that gap.

4.2 The regulatory framework for existing building assessment

Two distinct regulatory instruments govern the assessment of existing buildings in Istanbul, and the gap between them is central to understanding why the urban transformation programme operates as it does.

The first is TBEC 2018 Chapter 15, which provides a comprehensive performance-based framework for the seismic assessment of existing buildings. The framework defines performance targets at multiple hazard levels (DD-1 and DD-2), requires nonlinear analysis for complex cases, and produces a detailed quantitative assessment of a building's expected performance under scenario ground motions. When properly applied, it answers the question: what will this specific building do in an earthquake of a given return period, and what intervention – if any – is needed to bring it to an acceptable performance level? The framework also explicitly addresses retrofit: it provides methods for assessing the performance improvement achievable through various strengthening strategies, and enables a rational comparison between retrofit and replacement on seismic performance grounds. Crucially, the framework produces a spectrum of performance outcomes: a building may be assessed as providing continuous use, limited damage, controlled damage, or collapse prevention performance under different hazard levels. Some retrofitted buildings can be designed to sustain damage in a major earthquake while still targeting Life Safety performance. As one earthquake engineer described it in fieldwork conducted in Istanbul: "*once the risk is evaluated according to the Earthquake Code you will be able to see where you stand within the range of 'bad'...* [but] *these buildings will not collapse in the event of an earthquake*" (Kayaalp, 2025). This nuance – the difference between a building that will collapse and one that will be damaged but still protect the lives of occupants and limit injuries – is analytically critical for any rational urban transformation programme, because it determines which buildings genuinely require demolition and others where strengthening is a viable alternative option. The code provisions for the design of retrofits provide a practical approach; it recognizes that, depending on the building condition and original design, retrofitting to the same level of performance as for new construction may be uneconomic, too damaging to the fabric of building with cultural heritage value or simply too disruptive.

The second is the *Riskli Yapıların Tespit Edilmesine İlişkin Esaslar* (RBTE-2019), the simplified assessment methodology used to determine whether a building meets the risk threshold for mandatory action under Law 6306 (Republic of Türkiye, Ministry of Environment, Urbanisation and Climate Change, 2019). RBTE-2019 combines a critical-storey survey with a simplified linear-elastic analytical procedure to produce a binary outcome – at-risk (requiring demolition or further action) or not at-risk (no action required) – without the quantitative performance-level assessment that TBEC 2018 Chapter 15 provides. The methodology is broadly analogous in intent to the FEMA P-154 Rapid Visual Screening procedure used in the United States, though RBTE-2019 requires analytical calculation rather than sidewalk-level observation alone, and its output carries direct legal force under Law 6306 rather than serving as a prioritisation tool. It was designed as a screening tool to identify buildings warranting further investigation, not as a definitive assessment instrument. In practice, however, the RBTE-2019 designation is frequently treated as the basis for demolition decisions rather than as a trigger for the more detailed TBEC 2018 assessment that should follow – a process structured, as one structural engineer described it, to prove that a building is *çürük* (structurally unsound) rather than to assess the full range of technically available interventions (Kayaalp, 2025).

The consequence of this binary framing is that buildings which would survive a major earthquake – sustaining damage but not expected to collapse – are being designated as having an unacceptable level of risk and justifying the decision for them to be demolished, because the process is not designed to identify whether a building is safe for life but to confirm that it warrants demolition. As one engineer explained: "*In fact, it's probable that most of the buildings categorized as unsafe* [under Law No. 6306] *will prove safe for life*. *They will survive damage, and presumably, they will not kill* [people]. *Unfortunately, it is difficult to determine which ones will really kill*" (Kayaalp, 2025). The difficulty lies specifically in the limitations of the RBTE-2019 procedure: a detailed TBEC 2018 Chapter 15 assessment can distinguish between buildings that pose a genuine threat to life and those that would sustain repairable damage, but the Law 6306 process rarely proceeds to that stage. This assessment is consistent with the performance framework underlying the RBTE process itself: training materials for the regulation show schematically that buildings designated as risky are assumed to perform between the CG (*Can Güvenliği* – life safety) and GÖ (*Göçme Öncesi* – collapse prevention) levels, closer to GÖ, placing them in the advanced damage region rather than the collapse region of the force–deformation curve (Figure 17). The framework's designers were therefore aware that designated buildings retain life-safety potential – yet the legal process translates this nuanced performance assessment into a binary demolition trigger. The loss of this distinction – between buildings that are dangerous and buildings that are merely old and imperfect – is one of the most significant analytical failures of the Law 6306 implementation process.

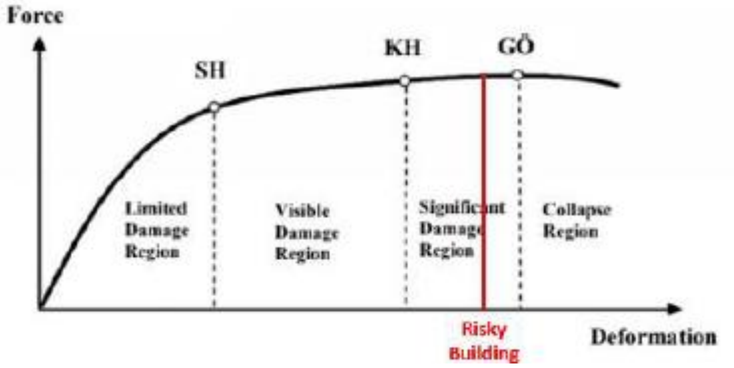


***Figure 17**: Assumed seismic performance level of buildings designated as risky under Law No. 6306, as represented in RBTE training materials. The risky building threshold (shown in red) falls within the Significant Damage Region – between the KH (Kontrollü Hasar) and GÖ (Collapse Prevention) performance levels – indicating that designated buildings retain life-safety potential despite their risky classification. The binary risky/not-risky legal outcome of the RBTE process does not capture this performance spectrum. Source: RBTE training materials (representative schematic).*

A critical gap in the regulatory process is the absence of any formal requirement to assess retrofit feasibility before a demolition decision is made. The RBTE-2019 designation that a building is risky does not constitute a finding that it is impractical to retrofit – yet no codified procedure exists within the Law 6306 process for determining whether strengthening to an acceptable performance level is technically feasible before the demolition route is authorised. The question of who decides a building is beyond retrofit, on what technical basis, and subject to what independent scrutiny, is not well defined in the regulatory framework.

The implementation of transformation works adds a further layer of complexity. Under Law 6306, transformation may be carried out by TOKİ, by licensed private contractors selected by the Ministry, or by contractors engaged collectively by building owners. Payment structures vary but frequently involve deferred settlement against future development value – the contractor is paid in part through allocation of units in the replacement building. This creates a structural incentive misalignment: the contractor's financial return is highest when they are able to maximise the floor area and unit count of the replacement building, not by minimising disruption to existing occupants or delivering the minimum intervention technically necessary. The procurement and payment architecture of the programme therefore reinforces the bias toward demolish-and-rebuild over retrofit at the project level, independently of the broader financial incentive structure discussed in Section §4.3. Following disputes between property owners and contractors that stalled progress in the programme's early years, a 2019 amendment to Law 6306 empowered the Ministry to undertake transformation projects ex officio and assign independent contractors directly – a change that further centralised decision-making and reduced the scope for building owners to choose retrofit over demolition (Legal 500, 2019).

A further historical note is instructive. When the World Bank financed the Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP) in 2006, it insisted that funds be used for retrofitting public buildings rather than demolish-and-rebuild. The private housing component was ultimately removed from ISMEP's scope because the Turkish state was unwilling to financially support private assets, and no legal framework for urban transformation had yet been enacted (Ay and Demires Ozkul, 2021). This is not merely a historical footnote:

it establishes that the bias toward demolish-and-rebuild in the private sector is a deliberate policy choice, not a technical necessity, and that an alternative approach – state-supported retrofit of private stock – was considered, costed and rejected.

4.3 The demolish-rebuild versus retrofit decision: evidence gaps and systemic bias

A fundamental limitation in evaluating the urban transformation programme is the absence of publicly available disaggregated data on its outputs. The Ministry of Environment, Urbanisation and Climate Change publishes cumulative statistics on buildings designated as risky and units delivered under the programme, but does not publicly report how many designated buildings have been brought to adequate seismic performance through structural intervention, how many have been demolished and replaced, and on what technical basis the route was chosen in each case. This absence is not a minor administrative gap: it makes it impossible to assess whether the programme is delivering the mix of interventions that the seismic engineering evidence would prescribe. Even the ISMEP megaproject – the most heavily resourced and institutionally supported component of Istanbul's risk mitigation effort – has been criticised for the opacity of its reporting against delivery targets (Ay and Demires Ozkul, 2021). What evidence is available for the private residential programme under Law 6306 suggests a strong bias toward demolition: only around 10% of buildings designated as risky are brought to adequate performance through structural intervention rather than demolished (Kayaalp, 2025).

Structural intervention – which may take the form of reinforced concrete column or beam jacketing, addition of RC shear walls, steel bracing frames, fibre-reinforced polymer wrapping of structural elements, or regularisation of infill walls – is technically feasible for a substantial proportion of Istanbul's vulnerable building stock, particularly those with concrete grades sufficient to sustain the demands of the retrofit intervention and with repairable structural configurations. For buildings with very low concrete grades (below approximately C10–C15, common in pre-1975 construction), structural intervention becomes increasingly impractical regardless of cost. But for a significant share of the pre-1999 stock – which spans a wide range of construction quality – the engineering assessment required by TBEC 2018 Chapter 15 would identify intervention as a viable and potentially preferable alternative to demolition. The 10% intervention rate strongly suggests that this assessment is not being conducted systematically before demolition decisions are made (Kayaalp, 2025).

What is clear from the programme's structure is that financial incentives strongly favour demolish-and-rebuild. Under Law 6306, owners of designated risky buildings receive state subsidies covering a portion of reconstruction costs, rent assistance during the construction period, and in most cases development rights uplift allowing the replacement building to be larger than the original. These incentives make demolish-and-rebuild financially attractive even where structural intervention would achieve equivalent seismic performance at lower cost. Structural intervention, by contrast, receives no equivalent financial support: there is no subsidy for intervention works, no rent assistance during the temporary displacement that major works require, and no state-backed performance guarantee for privately commissioned projects. Furthermore, property owners who proceed with structural intervention forfeit their entitlement to Law 6306's relocation assistance and development rights uplift (Kayaalp, 2025).

The barriers to structural intervention extend beyond the financial. Istanbul's dominant residential typology is the apartment block held under the *kat mülkiyeti* (condominium) system, where each flat is individually owned and major structural decisions require a supermajority of owners. Obtaining consensus for an intervention project – technically complex, disruptive and requiring sustained management – is substantially more difficult than agreeing to demolish and rebuild, where the state manages much of the process and provides financial incentives. The practical result is that structural intervention is disproportionately underutilised relative to its technical potential (Kayaalp, 2025).

The combination of two features of Law 6306 has also created a new construction market dynamic that operates independently of genuine seismic risk. First, the RBTE-2019 process will yield a risky designation for virtually all pre-1999 buildings regardless of their actual structural condition, because it applies current concrete grade standards to buildings constructed with earlier materials – meaning a building that would not collapse in a major earthquake but cannot meet current standards will be designated risky identically to one that would collapse. Second, a single property owner can initiate a risk assessment for an entire building without the consent of other residents. Construction companies have exploited this combination systematically: buying one or a few apartments in a pre-1999 building, applying for a risk assessment confident of the outcome, and using the resulting risky designation to force demolition and reconstruction – securing the reconstruction contract and development rights uplift in the replacement building (Kayaalp, 2025). The risk assessment, in these cases, is not the starting point of the process but the technical justification for a commercial decision already made. As one engineer described it: *"the starting point of Law No. 6306 is to prove that the building is çürük. The risk analysis is used as a technical justification for demolition. The real purpose is not to determine the condition of the building because it has already been decided to be renewed"* (Kayaalp, 2025). The colloquial Turkish term for this pattern – *deprem korkutmacılığı*, “earthquake scaremongering” – captures the concern that the threat of the anticipated major earthquake is being instrumentalised to deliver commercial value rather than resilience improvement (Kayaalp, 2025; Ay and Demires Ozkul, 2021).

The programme's reach also raises a question about the post-1999 stock that the focus on pre-1999 vulnerability tends to obscure. Approximately 30% of Istanbul's 1.6 million buildings were constructed after 1999, nominally under codes with mandatory *yapı denetim* building inspection. The 2023 Kahramanmaraş sequence demonstrated that code compliance and structural adequacy are not synonymous: numerous buildings constructed after 1999, some after 2007, collapsed despite nominally meeting code requirements (Aktas et al., 2024; Vuran et al., 2025). The inspection regime – introduced specifically to prevent the construction quality failures that drove the 1999 collapse toll – demonstrably did not function as intended across all sites. The 2019 reform requiring inspection firm assignment by lottery rather than contractor selection has reduced one vector of corruption, but whether it has resolved the underlying incentive misalignment is not yet established. The consequence for the urban transformation programme is significant: If replacement buildings are being constructed under the same quality regime that produced vulnerable post-1999 stock elsewhere in Türkiye, the programme may be replacing old deficient buildings with new deficient ones, and the seismic risk reduction it delivers will be less than its output statistics imply. This concern is not hypothetical: analytical investigation of a 2006-built Istanbul building designated as risky under Law 6306 documented sub-code reinforcement ratios in ground floor columns and shear walls, stirrups not closed at the code-required 135 degrees, and concrete strengths of only 16-22 MPa – deficiencies indistinguishable from those characteristic of pre-1999 construction, in a building nominally subject to post-1999 inspection requirements (Dede and Hancılar, 2022).

This matters for two further reasons. First, many buildings that are technically capable of being brought to adequate seismic performance through structural intervention are being demolished unnecessarily – generating embodied carbon emissions, displacing communities and erasing neighbourhood fabric – when structural intervention would often achieve equivalent or comparable, or at the very least acceptable, seismic performance outcomes at lower cost and disruption. Second, the programme's outputs are not consistently directed toward the buildings and districts most in need of intervention. As Ay and Demires Ozkul (2021) document, urban renewal claiming earthquake risk mitigation has effectively mandated land rent maximisation as its financing mechanism, prioritising redevelopment where returns to real estate investment are highest rather than where seismic risk is greatest. The five European-side districts generating the highest damage report concentrations in 2025 – Bahçelievler, Esenler, Bağcılar, Zeytinburnu, Esenyurt – are precisely those where the financial case is least compelling without substantial state subsidy. The result is a programme operating most intensively in areas of moderate risk and high land value, and most slowly in areas of highest risk and lower land value.

The most documented cases of transformation-driven displacement in Istanbul are Sulukule and Fikirtepe. Sulukule, a historic Roma neighbourhood in Fatih, was demolished between 2007 and 2009 under urban renewal legislation; the replacement housing was priced well beyond the means of the original community, who were relocated to Taşoluk on the city's periphery – approximately 40 km from their original neighbourhood (Kuyucu and Unsal, 2010; Karaman, 2013). In Fikirtepe, fieldwork conducted as part of the Tomorrow's Cities project documented residents of an established neighbourhood caught between rising residential towers, describing displacement that was cultural as well as financial: a way of life built around semi-outdoor communal living – gathering on doorsteps, in gardens, with doors and windows open across seasons – that was structurally incompatible with the residential tower culture replacing it. Residents reported outmigration not only due to unaffordable replacement housing but due to the loss of a neighbourhood fabric and social environment that could not be reconstructed in the new development (Rossetto et al., 2022; MAR-028). Neither case is exceptional; both are documented instances of the displacement pattern that Kayaalp's (2025) fieldwork in Kadıköy and Ay and Demires Ozkul's (2021) broader analysis document as structurally embedded in the programme's financial logic.

4.4 Carbon and societal costs of large-scale urban transformation

The carbon cost of the urban transformation programme has received almost no attention in the policy discourse surrounding it. The construction of a new reinforced concrete building requires approximately 300–400 kg CO_2 equivalent per square metre of floor area, depending on structural system, concrete mix and reinforcement intensity (IPCC, 2022). The scale of the private residential transformation programme under Law 6306 is not publicly reported in disaggregated form, but the programme has delivered hundreds of thousands of replacement residential units since 2012, in addition to the over 1,000 school buildings and 115 health facilities prepared under the ISMEP project (Ay and Demires Ozkul, 2021). The aggregate embodied carbon of the private residential transformation programme has not been formally assessed; at the scale required to address the full risk profile identified in the scenario loss studies, the carbon cost would run to tens of millions of tonnes of CO_2 equivalent – a significant fraction of Türkiye's annual construction sector emissions.

This carbon expenditure would be justified if demolish-and-rebuild were consistently the only technically viable option and if it reliably delivered the promised seismic performance improvement. Neither condition is reliably met. For buildings with concrete grades above C-10, structural intervention to adequate seismic performance levels is technically feasible and typically requires 20–40% of the embodied carbon of a full replacement building (Contreras et al., 2022; IPCC, 2022). The programme's failure to systematically evaluate structural intervention as an alternative means that the carbon expenditure being incurred is not optimised against the resilience benefit delivered. Furthermore, as discussed in §4.3, the structural design, construction quality and inspection regime that produced vulnerable buildings in the pre-1999 stock has not been demonstrably resolved in new construction: if replacement buildings are subject to the same enforcement failures, they may replicate structural vulnerabilities in a modern geometric configuration, in which case the resilience justification for the carbon expenditure is itself undermined.

The societal costs are equally significant and similarly unaccounted. Urban transformation at scale displaces communities, destroys social networks, eliminates affordable housing stock and erases neighbourhood fabric that took generations to develop. In Istanbul, the transformation programme has in multiple cases been applied to neighbourhoods with historic significance, functioning social infrastructure and cultural identity that cannot be rebuilt alongside the replacement apartment blocks. Some of these mechanisms have been recorded by the Tomorrow's Cities project (Rossetto et al., 2022). The loss of assembly areas documented in Chapter 9 – 419 of 496 post-1999 designated areas converted to commercial or residential development – is partly a product of the transformation programme itself, as densification of replacement buildings reduces the open space available for assembly use. The community and social displacement costs of the programme have not been formally assessed against its resilience benefits, and no framework currently exists for making this comparison.

A further dimension of the programme's societal cost is the gentrification dynamic it enables and accelerates. Urban transformation under Law 6306 consistently produces replacement buildings of higher floor area, higher specification and higher market value than the buildings they replace. Where the original occupants are tenants, rent assistance during construction is temporary and replacement units are frequently priced beyond their means – displacing them permanently from neighbourhoods they have occupied for decades. Where occupants are owners, the development rights uplift creates windfall gains that attract speculative interest, accelerating the turnover of ownership toward higher-income households. The cumulative effect, documented across multiple transformation zones in Istanbul including in Kadıköy and Sulukule (Kayaalp, 2025; Kuyucu and Unsal, 2010; Karaman, 2013), is the progressive displacement of lower-income communities toward the urban periphery – which, as established in Chapter 3, is also where seismic risk is concentrated in newer, less well-inspected stock on less well-characterised ground conditions. As Ay and Demires Ozkul (2021) argue, urban renewal claiming earthquake risk mitigation has effectively mandated land rent maximisation as its financing mechanism, prioritising redevelopment where returns to real estate investment are highest rather than where seismic risk is greatest – with the result that earthquake risk becomes, in their words, *"a red herring"* in a process primarily driven by real estate economics. The programme is subsidised by the state and marketed as a safety intervention, while delivering outcomes that align more closely with the interests of the construction and real estate sectors than with those of the communities it nominally serves. This circularity – a risk reduction programme that simultaneously increases the exposure of the most vulnerable – has not been formally recognised in the programme's design or evaluation framework.

The design principles governing replacement buildings under the transformation programme deserve scrutiny beyond their seismic adequacy. Current planning regulations permit replacement buildings to be taller and denser than the structures they replace, reflecting both the development rights uplift provisions of Law 6306 and the contractor payment structures described in §4.2. The result is transformation zones characterised by replacement buildings with more floors, more units and smaller average unit sizes – a typological shift driven by development economics rather than by the housing needs of the displaced community or by any assessment of neighbourhood character. The densification that transformation produces reduces available open space, increases demand on local infrastructure and further erodes the per-capita assembly area provision that was already inadequate before the programme began (Chapter 9).

A further and largely overlooked consequence of the transformation programme concerns the progressive elimination of balconies from new residential stock. Under the *Planlı Alanlar İmar Yönetmeliği* (Planned Areas Zoning Regulation, Republic of Türkiye, 2017, Article 4), permitted floor area is calculated as a function of plot area and *emsal* (floor area ratio). The regulatory treatment of enclosed balconies within *emsal* calculations has progressively tightened, removing the design incentive to include them and creating strong commercial pressure to eliminate balconies in order to maximise lettable internal floor area within the permitted envelope (Articles 5 and 22 of the regulation). The practical consequence, visible across Istanbul's transformation zones, is a generation of new apartment buildings constructed without balconies – or with nominal balconies too small for functional use.

The significance of this is not structural. The balcony was a fundamental element of Istanbul's traditional apartment culture: the only outdoor space accessible without leaving the building, used for social interaction with neighbours and for the informal daily rhythms of apartment life that sustain community cohesion in dense urban neighbourhoods. Balconies also serve important environmental functions – contributing to natural ventilation, providing space for planting that can reduce indoor temperatures during heatwaves, and supporting occupant wellbeing in a city facing increasing climate stress. Their elimination in new-build transformation stock impoverishes the living environment of the communities being rehoused – a loss that is invisible in the programme's output statistics, unaddressed in its design criteria, and irreversible once the neighbourhood fabric that took generations to develop has been demolished and replaced.

4.5 What the 2025 event reveals about the programme

This chapter has focused on the private residential building stock targeted by Law 6306. The 2025 earthquake provides the first real-world opportunity to assess how a decade of transformation activity has affected Istanbul's vulnerability profile under moderate seismic loading. The event must be interpreted carefully: recorded ground motions remained well below DD-2 design levels across all stations, meaning it did not constitute a genuine structural test of either the old or the replacement stock at design level. What it provides is a set of signals - some consistent with programme intent, others raising significant questions – that should inform how the programme is designed and directed going forward.

The pattern most consistent with programme intent is the spatial correspondence between the highest damage report concentrations and the districts with the highest proportions of pre-1999 RC building stock. The five European-side districts generating the most damage reports – Bahçelievler, Esenler, Bağcılar, Zeytinburnu, Esenyurt – are precisely those identified as highest-risk in every scenario loss study since 2002 and those with the lowest proportions of post-1999 stock. This spatial correspondence confirms what the scenario studies predicted, and it is consistent with the hypothesis that older stock performs worse than newer stock under equivalent sub-design loading. What it does not establish – given the ground motions were well below design level – is that the programme's replacement stock is adequate for the anticipated major event. The absence of collapse or significant damage in post-1999 buildings at sub-design loading is uninformative about their performance at design level.

The spatial pattern, however, is the less important signal from the 2025 event. The more troubling evidence concerns construction quality. The core question the programme must answer is not whether it is replacing old buildings with new ones, but whether it is replacing deficient buildings with adequate ones. The 2023 Kahramanmaraş sequence established at catastrophic scale that code compliance on paper does not guarantee structural adequacy in practice – buildings nominally compliant with post-1999 and post-2007 codes collapsed because construction quality and *yapı denetim* inspection failed (Aktas et al., 2024; Vuran et al., 2025). The 2025 evidence does not resolve whether Istanbul's transformation programme is producing genuinely adequate replacement stock or replicating the same construction quality failures in modern structural geometry. The fractured columns containing mussel shells (*midye kabukları*) documented in Küçükçekmece (MAR-030, MAR-037; MAR-057) demonstrate that the type of construction deficiency associated with the 2023 collapse toll is present in Istanbul's building stock under moderate loading. The construction period of the affected building is not established from the available evidence; what the observation establishes is not a finding about the transformation programme specifically, but a finding about the persistence of construction quality failure as a systemic feature of Istanbul's built environment that the inspection regime has not consistently resolved – whether in buildings constructed before or after the 1999 reforms.

The question of programme geography is where the 2025 event provides its clearest and most actionable signal. The districts generating the highest damage report concentrations are not the districts where transformation activity has been most intensive. As Ay and Demires Ozkul (2021) document and the 2025 evidence reinforces, the programme has been operating most actively where land values support its financial model, not where seismic risk is greatest.

Whether any public dataset exists that would allow systematic comparison of Law 6306 delivery rates against the damage report geography of the 2025 earthquake is not known to the authors. If such data were compiled and published by the Ministry, it would be one of the most useful analytical inputs to programme planning currently available. EEFIT recommends this as a priority task. In particular, whether systematic spatial overlap exists between Law 6306 programme delivery and the IMM disaster-priority areas identified by IMM/KOERI (2019) warrants formal analysis.

The 2025 earthquake did not test the replacement building stock at design level. Whether that stock – built by the same industry, subject to the same inspection regime, designed to the same codes – will perform as its certificates imply when it faces its design-level test remains open. The programme has, at best, reduced the proportion of the stock that is most obviously inadequate by pre-1999 standards. Whether it has produced replacement stock that is genuinely resilient, or replacement stock that is adequately designed but inadequately built, is the most consequential unanswered question about Istanbul's earthquake preparedness that the 2025 event leaves on the table.

4.6 Conclusions

Istanbul's urban transformation programme under Law 6306 is the most significant policy intervention currently available for reducing seismic risk in the city's residential building stock before the anticipated major event. It is important to distinguish this programme from Türkiye's publicly funded seismic risk mitigation efforts for critical infrastructure. The ISMEP programme (Istanbul Seismic Risk Mitigation and Emergency Preparedness Project) and related World Bank-supported initiatives have assessed and retrofitted thousands of schools, hospitals and public buildings since 2006, and the broadly satisfactory performance of retrofitted school buildings during the 2023 Kahramanmaraş earthquake sequence demonstrates that well-implemented assessment and retrofit of existing buildings works. The residential programme operates under a fundamentally different model – developer-led, financially dependent on land-value uplift, and overwhelmingly oriented toward demolition and reconstruction rather than retrofit – and it is this programme's design and outcomes that this chapter has examined.

The evidence suggests that the programme is operating at a scale far below what the residual risk requires, and that its design and implementation contain structural flaws that limit its effectiveness even where it is active. The gap between the rigorous performance-based assessment framework provided by TBEC 2018 Chapter 15 and the simplified screening process that drives programme decisions means that many demolition decisions are not grounded in a formal evaluation of whether retrofit would achieve equivalent performance at lower cost. The financial incentive structure of Law 6306 systematically favours demolish-and-rebuild over retrofit, directing programme resources toward areas of high land value rather than areas of highest seismic risk. The carbon and social costs of operating a demolition programme at this scale have not been formally weighed against the resilience benefits delivered. And the design and construction quality problems that drove the 2023 catastrophe appear to persist in new stock, raising questions about whether the programme is replacing vulnerable buildings with resilient ones or simply replacing old vulnerable buildings with new ones.

None of these problems is technically intractable. The public-building programme demonstrates that Türkiye possesses the regulatory architecture, engineering capacity and institutional capability to deliver effective seismic risk reduction of existing buildings. A residential programme that required TBEC 2018 Chapter 15 assessment before demolition decisions, that provided retrofit subsidies equivalent to the reconstruction subsidies currently available, that directed state resources toward the highest-risk districts rather than the highest-value land, and that enforced the yapı denetim inspection regime consistently in new construction would address all of the deficiencies documented in this chapter. The regulatory architecture for such a programme exists. The political economy that would make it operate in this way does not yet.

The 2025 earthquake, by confirming the spatial vulnerability pattern that the scenario studies have documented since 2002 – at sub-design loading, before the major event – represents an opportunity to recalibrate the programme toward the districts and buildings that need it most, using the technical methods that the codes already provide. Whether that opportunity is taken is, once again, a question of political will and institutional capacity that lies beyond this report's scope to answer, but not beyond its scope to ask.

5 Preliminary Urban Damage Prediction from Recorded Ground Motions

Chapter summary in plain terms

This chapter uses the 2025 ground motion records to predict how much structural damage the earthquake might have caused in Istanbul's building stock, and what this implies for the anticipated major event. The analysis compares recorded shaking levels with the reduced design spectra that underpin Turkish seismic code, showing that inelastic deformation was likely in vulnerable building typologies in Küçükçekmece, Bakırköy, Avcılar and Silivri even at sub-design loading. The key finding is that Avcılar recorded both the highest damage potential and the longest shaking duration of all analysed stations, consistent with known site conditions in that district that produced anomalously high damage in the 1999 earthquakes. Station 3415 (Küçükçekmece) shows anomalous short-period amplification relative to stations at comparable distances, pointing to an additional site-specific vulnerability for low-rise construction in that district. The analysis is validated by an independent study of 38,049 Istanbul buildings, which found that limited damage in 2025 reflects the short duration of shaking rather than structural adequacy. Under the anticipated Mw 7+ rupture, the same building stock would face sustained inelastic cycling rather than the brief threshold exceedance of 2025 – a qualitatively different loading regime that would drive cumulative damage to collapse in buildings that appeared to survive 2025 undamaged.

5.1 Introduction and motivation

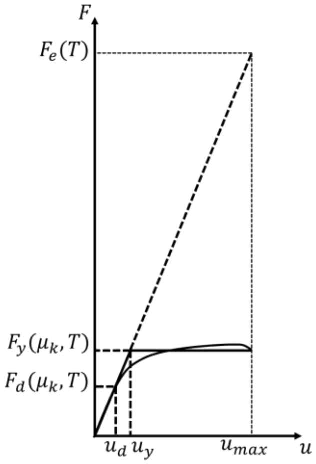
The discussion in Chapter 2 (Section §2.5.3) shows that the 23 April 2025 earthquake has generated ground accelerations lower than the corresponding code DD-2 level ground motions at all locations where the stations are situated. While PGA is extensively used to quantify shaking severity, it is a poor predictor of structural damage except for very stiff, short-period structures (Giovenale et al., 2004; Jalayer et al., 2012; Hancılar and Cakti, 2015). One of the most commonly used intensity measures (IMs) as a predictor of the structural damage is the spectral acceleration at the period of vibration of the first mode, $S_a(T_1)$.

$S_a(T_1)$ is also the basis parameter in the strength-based design approach as per the former and current versions of Turkish seismic codes, TEC 1998/2007 and TBEC 2018, respectively. Design-basis earthquake forces in the strength-based design approach for building structures are estimated with an explicit consideration of ductility and overstrength, which is achieved by down-scaling the DD-2 level elastic spectral accelerations by an earthquake load reduction factor (R_a), similar to the q-factor approach adopted in Eurocodes. Seismic loads are then obtained by multiplying the reduced spectral accelerations and seismic mass, as shown in the following generic equation:

$$E_d = S_{aR}(T) \times M = \left(\frac{S_{ae}(T)}{R_a(T)}\right) \times M \qquad (1)$$

where E_d is the design earthquake load, $S_{aR}(T)$ is the reduced spectral accelerations, M is the seismic mass, $S_{ae}(T)$ is the elastic design spectral accelerations, and $R_a(T)$ is the load reduction factor. Albeit the variations in the actual values due to differences between TEC 1998/2007 and TBEC 2018, it can be stated that the generic equation given in Eq. (1) represents the basis principle used to design the majority of the code-compliant buildings, considering that the strength-based design represents the most common practice for designing ordinary buildings in Türkiye.

The R_a factor used to obtain S_{aR} in Eq. (1) is prescribed for different structural systems in the Turkish seismic codes, accounting for the overstrength and ductility ought to be provided through ductile design principles for the chosen system. The schematic representation of the load-displacement response of a single-degree-of-freedom system (SDOF) shown in Figure 18 illustrates the underlying rationale of strength-based design with the R_a factor. Its adoption entails the premise that overstrength and ductility capacity ought to be introduced into the system by appropriate design and detailing so that the chosen R_a factor can be accommodated.



$$R_a(T) = \frac{F_e(T)}{F_d(\mu_k, T)} = DR_y(\mu_k, T)$$

μ_k : Ductility capacity of the structure
T : Period of the first mode of vibration
$F_e(T)$: Linear-elastic earthquake force demand
$F_y(\mu_k, T)$: Yield strength of the structure
$F_d(\mu_k, T)$: Design strength of the structure
$R_y(\mu_k, T)$: Yield strength reduction factor

Figure 18: *Schematic representation of estimation of design forces in strength-based design (Adapted from TBSC 2018)*

As shown by the ratio of the yield strength to the design strength in Figure 18, the actual strength of the structures with code-compliant design should be higher than the design strength, representing the overstrength in the design. However, observations of the poor material quality and workmanship as well as non-compliant design and applications from the Mw 7.8 and Mw 7.5 earthquakes in February 2023 (Aktas et al., 2024; Vuran et al., 2025) suggests that anticipated overstrength is not always achieved in practice, and the actual overstrength of the structure can be considerably lower than the anticipated values (Yakut, 2008). In light of this discussion, we also compare recorded spectral acceleration demands with the reduced design spectra to investigate whether the demand exceeds the values that are basis to design.

5.2 Method

In this regard, to conduct a preliminary investigation, elastic and reduced design spectra are constructed at stations with existing $V_{s,30}$ data and compared with the recorded response spectra at these stations. To make this investigation more comprehensive, TEC 1998/2007 and TBEC 2018 are considered as a signification portion of buildings in Istanbul constructed before 2018. Also, the investigation herein is kept limited to RC frames considering the data produced in the 2019 Istanbul Province Possible Earthquake Loss Estimates Update Project (IMM and KOERI 2019), which reports there are almost 1.2 million buildings in Istanbul's building stock, and around 82% of these buildings are reinforced concrete (RC) frames.

For RC frames in areas of high seismicity, TEC 1998/2007 and TBEC 2018 prescribe high-ductility detailing and permits use of R_a = 8. Accordingly, recorded response spectra is compared with the design spectra as per both regulations, adopting R_a = 1 and R_a = 8. Figure 19 shows the stations for which these comparisons are made. Among the studied stations, Station 3429 is closest to the epicentre, and Stations 3428, 3415, and 3416 are situated within ~50 km of the epicentre. Figure 19 also shows epicentral distances of the remaining stations along with the $V_{s,30}$ data and associated site classes as per TBEC 2018. Parallel to the data shown in Figure 8 of Section §2.5.1, stations are mostly situated over relatively weaker soil layers (predominantly ZC and ZD classes). Such site conditions are generally associated with amplification of intermediate- to long-period ground motion content, which has implications for the response of mid-rise and taller structures – the dominant building typology in Istanbul's most vulnerable districts.

Station ID	R_{epi} (km)	$V_{s,30}$ (m/s)	Site Class
3405	76.9	1862	ZA
3407	67.7	596	ZC
3410	119.6	587	ZC
3411	63.7	323	ZD
3413	64.6	452	ZC
3415	47.0	283	ZD
3416	51.3	420	ZC
3417	85.7	1747	ZA
3425	72.4	526	ZC
3426	70.4	667	ZC
3427	71.0	761	ZB
3428	43.0	318	ZD
3429	25.0	230	ZD
3430	79.3	379	ZC

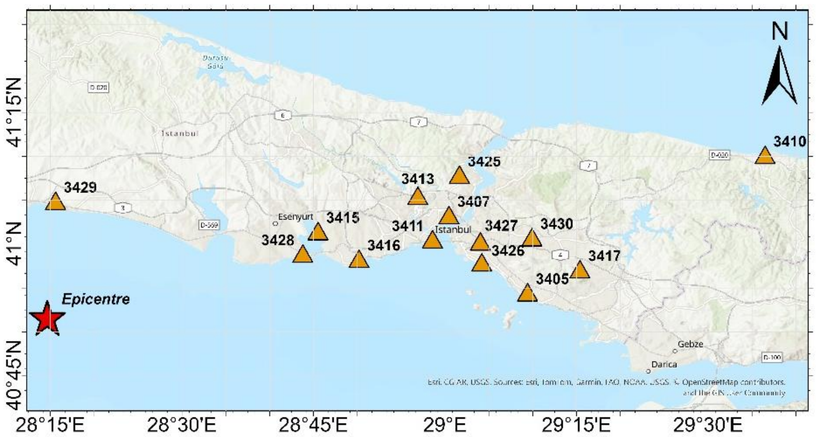


Figure 19: *Locations and site characteristics (epicentral distance, V~s,30~, TBEC 2018 site class) of the strong-motion stations used in the ESDOF analysis.*

In order to examine whether there are structures that exhibited inelastic deformations and the extent of which, SDOF structures can be adopted here as a computationally efficient option to assess variety of structures for provided stations. The use of equivalent SDOF (ESDOF) structures in earthquake engineering to assess the seismic response of the building population is an established strategy and has been successfully adopted in urban seismic risk assessment studies. In the following part of this section, the ESDOF models presented in Karimzadeh et al. (2018) is utilised for the numerical assessment of inelastic structural response. These models are developed for the building stock in the city of Erzincan and represent the idealised system-level inelastic response of various RC frame subclasses, which address different height classes, lateral-load bearing systems, and levels of seismic design compliance (Karimzadeh et al., 2018).

Karimzadeh et al. (2018) provides several basic parameters of ESDOF models, characterising the nonlinear structural response, namely, period (T), strength ratio (Ω), ductility factor (μ), elastic (initial) stiffness parameter (α_s), the ratio of the post-capping stiffness to the elastic stiffness (α_c), cyclic deterioration parameter (β), and hysteretic energy dissipation parameter (γ). Among these, the first three parameters, i.e., the structural parameters (T, Ω, μ), are suggested to be treated as random variables and the remaining parameters, i.e., hysteretic model parameters (α_s, α_c, β, γ), are suggested to be treated as fixed values. Interested readers are referred to Karimzadeh et al. (2018) and Askan et al. (2015) for further information on modelling parameters of ESDOF models' hysteretic response as well as data collection and classification.

For the purposes of the preliminary assessment herein, the dataset of ESDOF models generated by Gökmen (2025) is used. Gökmen (2025) utilised Latin-Hypercube Sampling (LHS) methodology to generate a pool of 120 SDOF models treating T, Ω, and μ as random parameters. Same ESDOF models are generated herein as well, based on the provided values, and time history analyses are conducted at each station in Figure 19. Following the recommendations by Karimzadeh et al. (2018), Modified Ibarra-Medina-Krawinkler Deterioration Model (see Ibarra et al., 2005) in OpenSees (v. 2.4.5) is used to model ESDOF structures. Each of 120 ESDOF models response under the recorded acceleration data are then compared with the limit state thresholds provided for each subclass of buildings by Karimzadeh et al. (2018).

5.3 Results

Figure 20 presents the recorded response spectra along with the elastic (R_a = 1) and reduced (R_a = 8) design spectra for each station. As expected, in light of the previous discussions (Section §2.5.3), recorded acceleration response spectra remain below the DD-2 level elastic design spectra in all cases. Figure 20 also illustrates the attenuation of seismic demand with increasing distance from the epicentre. One strong exception to the attenuation is recognised in Station 3415, where the spectral response of short-period structures with periods shorter than ~0.3 sec is significantly amplified.

When recorded response spectra are compared with the reduced design spectra in Figure 20, it can be seen that recorded values exceed the reduced design spectra at multiple stations across a range of structural periods, suggesting that inelastic deformations could be expected (depending on the overstrength) for buildings having their fundamental mode of vibrations in these ranges.

Table 3 presents the examined subclasses of RC frames, range of the corresponding T_1 values, and stations where immediate occupancy limit state (LS_1) is exceeded along with the percentage of these cases. In Table 3, classifications of the subclasses are as presented in Karimzadeh et al. (2018), where the first two letters represent RC frame (RF), the following number indicates the height class (1 = low-rise, 1–3 storeys; 2 = mid-rise, 4–8 storeys), and the letter in the last position (A, B, or C) denotes the level of seismic design compliance (A = high, B = moderate, C = low). Corresponding to each of these subclasses in the next column are the structural periods of the ESDOF mode following the previously described parameters (Gökmen, 2025). Stations 3415, 3416, 3428, and 3429 are situated in Küçükçekmece, Bakırköy, Avcılar, and Silivri districts of Istanbul, respectively.

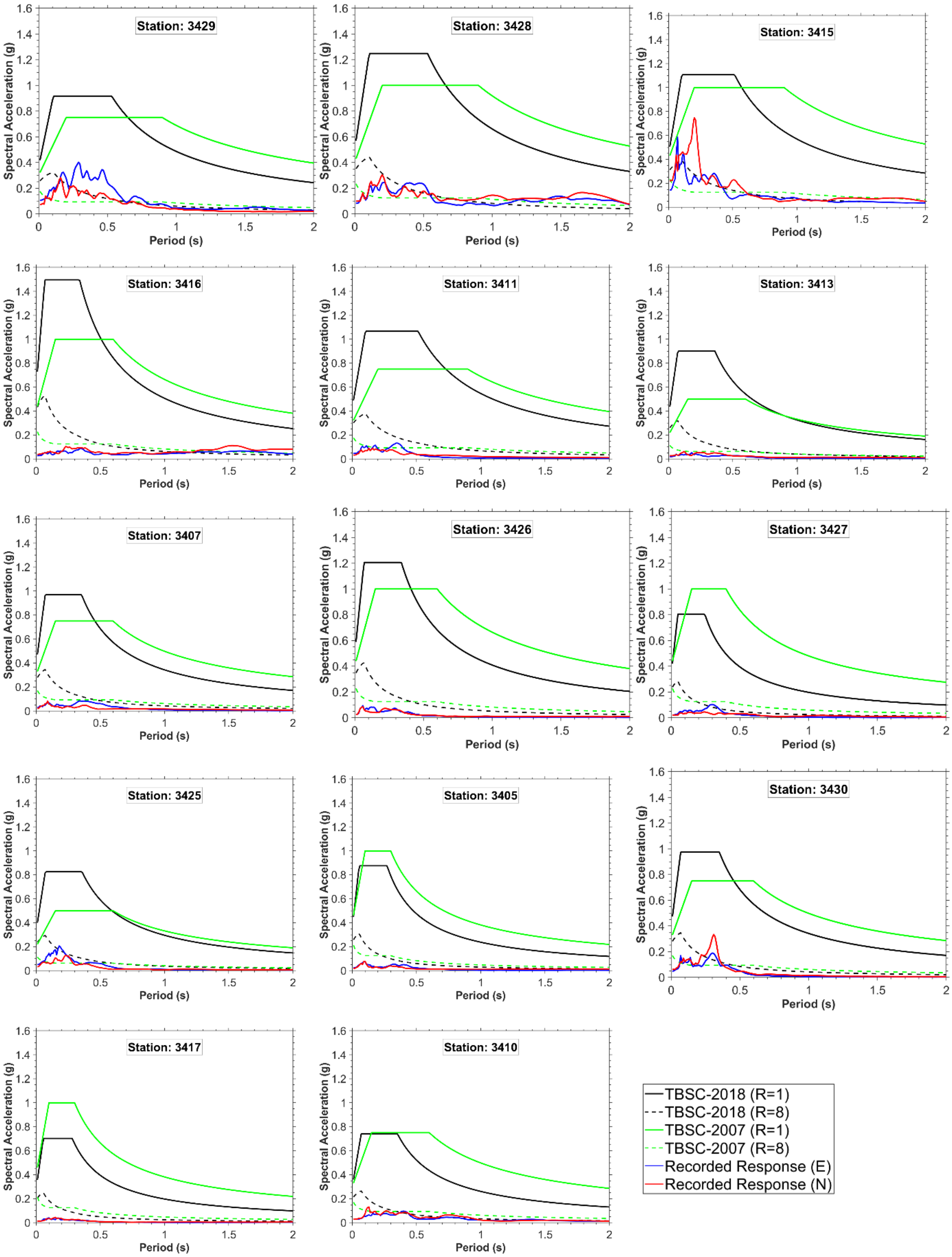


Figure 20: *Comparison of recorded elastic response spectra (5% damping) with elastic (Ra = 1) and reduced (Ra = 8) design spectra at the 14 examined stations, for both EW and NS components, ordered by increasing epicentral distance from Station 3429 (Silivri, 25.0 km) to Station 3410 (Şile, 119.6 km). The ordering allows the attenuation of spectral demand with increasing distance to be followed directly across the panels. Recorded spectra remain below DD-2 elastic design levels at all stations. At multiple stations, recorded spectra exceed the reduced design spectra (Ra = 8) across a range of structural periods, indicating potential inelastic demand in buildings with fundamental periods in those ranges depending on actual overstrength. Station 3415 (Küçükçekmece, ZD soil, 47.0 km) shows notable short-*

period amplification relative to neighbouring stations at comparable distances. Station 3428 (Avcılar, ZD soil, 43.0 km) records relatively larger spectral accelerations beyond T = 0.5 s despite its intermediate epicentral distance, consistent with known site amplification effects in this district.

Table 3: *Examined RC frame subclasses and percentage of cases exceeding LS_1*

Structure	Range of T_1 values (s)	Station 3415		Station 3416		Station 3428		Station 3429	
		E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S
RF1A	0.08-0.73	0%	5%	0%	11%	16%	37%	5%	0%
RF1B	0.01-0.83	5%	5%	5%	5%	11%	26%	5%	0%
RF1C	0.07-1.03	5%	10%	5%	10%	15%	20%	5%	0%
RF2A	0.24-1.32	0%	11%	11%	42%	47%	63%	0%	0%
RF2B	0.10-1.27	0%	24%	24%	35%	47%	65%	12%	0%
RF2C	0.24-1.50	0%	32%	16%	37%	58%	63%	16%	0%

Amongst the stations presented in Figure 19, stations 3415, 3416, 3428, and 3429 induced top displacements on ESDOF models that exceeded LS_1, indicating slight damage. These results are also parallel to the comparisons in Figure 20 as the recorded spectra exceeds the reduced design spectra (R_a = 8) across a similar range of T_1 values in Table 3. While total number of cases per each subclass and the distribution of structural periods covered by these cases remain limited for a detailed statistical inference, results suggest the stations presented in Table 3 registered ground shaking that could lead to slight damage.

Table 1 also reveals that Station 3428 records substantially longer strong motion durations than the other three stations: D5-95 values of 40.68 s (EW) and 32.34 s (NS), compared with a range of 10.75–23.70 s across the remaining stations. The combination of larger long-period spectral accelerations and longer strong motion duration at Avcılar is analytically significant: duration amplifies cumulative inelastic damage beyond what spectral amplitude alone predicts, and suggests that Avcılar's building stock is exposed to a compounded vulnerability that PGA-based or spectral-based assessments may underestimate.

5.4 Discussion and conclusions

Results also suggest recorded ground shaking in Avcılar (Station 3428) results in higher rates of ESDOF models in LS1 compared to other stations. Figure 20 shows that this particular station registered relatively larger ground shaking beyond T_1 = 0.5 sec compared to others, albeit it not being the closest to the epicentre. The influence of geological conditions in Avcılar district was also observed through the relatively higher rates of building damage during Mw 7.4 Kocaeli and Mw 7.2 Duzce earthquakes in 1999 (Erdik, 2001).

The D5-95 data reinforce this interpretation. The exceptionally long strong motion duration at Station 3428 – more than twice that of Station 3415 at comparable epicentral distance – is consistent with basin resonance effects prolonging shaking in the Avcılar area, a phenomenon documented following the 1999 Kocaeli earthquake (Erdik, 2001). Under the anticipated Mw 7+ event, both the spectral amplitude and the duration of shaking at Avcılar would be substantially greater than observed in 2025, compounding the already elevated inelastic demand shown in Table 3.

For Küçükçekmece, Bakırköy, Avcılar, and Silivri districts of Istanbul, similar inferences of slight damage were also made by Hancılar et al. (2025) for Mw 6.2 Western Marmara Sea earthquake of 23 April 2025, where they report damage estimates utilising the registered ground motion data by KOERI network and a building inventory derived for Istanbul in 2018. Based on the urban risk assessment application results, they suggested that slight damage to the structures in these districts could be observed.

These findings carry an important forward implication. The damage assessed here is slight – consistent with the observed outcomes. But it occurred at stations where recorded ground motions remained well below DD-2 design levels, and under an event characterised by relatively short source duration. The significant duration (D5-95) of recorded ground motions varies considerably across stations and components, ranging from approximately 11 seconds (Station 3415, NS component) to approximately 41 seconds (Station 3428, EW component). Station 3428 (Avcılar) shows both the largest long-period spectral accelerations and the longest strong motion duration of the four stations, compounding the potential for inelastic cycling damage beyond what PGA values alone would suggest. A longer-duration event of comparable PGA, as would be produced by the anticipated Mw 7+ rupture on the Princes' Islands segment, would subject buildings across all four districts to sustained inelastic cycling rather than brief exceedance of the reduced design spectra.

6. Observed Impact: Built Environment

Chapter summary in plain terms

This chapter documents what the 2025 earthquake physically did to Istanbul's buildings, infrastructure and heritage. Structural damage was light and geographically concentrated on the European side, in exactly the districts that engineering analysis has long identified as highest-risk. Three buildings partially or fully collapsed, all of them unoccupied or derelict. Fractured columns containing mussel shells used as aggregate substitute were documented in Küçükçekmece – a construction defect that points to potentially widespread hidden vulnerability in the pre-1999 stock. An independent study of 38,049 Istanbul buildings found that limited damage in 2025 reflects the short duration of shaking, not structural adequacy: the same buildings would not survive a longer-duration record of comparable PGA – the most important engineering conclusion the chapter draws.

Lifeline systems including early warning, gas shut-off and base-isolated hospitals performed well. The single significant infrastructure failure was mobile telecommunications saturation, a vulnerability unresolved since 1999. Four schools were evacuated on structural grounds within a week of the earthquake, following official assurances on the day that no schools had been damaged. A further governance failure: 199 buildings in Avcılar documented as moderately damaged in the 1999 earthquakes had never been demolished or evacuated and remained occupied on 23 April 2025, their legally-mandated remediation deadline having passed in 2020.

6.1 Introduction and evidence base

A systematic social media evidence log was compiled to cover the period 23 April–30 May 2025 and draw on publicly accessible posts from X (formerly Twitter) and Instagram, identified through keyword searches in Turkish and English targeting the following themes: building damage documentation, evacuation and assembly area behaviour, governance and official communication, lifeline performance, and economic response including insurance system performance. Each entry was assigned a unique reference identifier (MAR-001 to MAR-073) and logged with platform, date, author type, location, media type, and a content summary; entries from MAR-054 onwards were collected by the lead author independently. The full log is presented in Annex A. Social media evidence is cited throughout Chapters 5, 6 and 7 to document observations and experiences not captured in official datasets. It is not treated as statistically representative; it is used as qualitative corroborating or contradicting evidence alongside instrumental, official and crowdsourced data sources, and all cited entries can be verified against the Annex A record.

6.2 Building damage

A total of 6,539 building damage reports were submitted by residents to the Ministry of Environment, Urbanisation and Climate Change in the days following the earthquake (Kurum, 2025c). By 29 April, 25,017 buildings had been assessed by ministry teams; of these, 2,928 were classified as having sustained some damage (Kurum, 2025b; MAR-006). These figures describe successive stages of the same assessment process and should not be conflated: citizen damage reports trigger inspection but do not themselves establish damage, and the majority of inspected buildings were found undamaged. By 1 May, with 36,000 buildings comprising 425,000 independent units assessed, 27,697 buildings had been confirmed undamaged and 4,295 classified as slightly damaged (*az hasarlı*) – the figure used elsewhere in this report – with slightly-damaged owners declared eligible for the *Yarısı Bizden* support programme (Kurum, 2025a). The distribution of damage reports by district is strongly concentrated on the European side of Istanbul: approximately 80% of all reports originated from European-side districts, consistent with the spatial distribution of higher recorded ground motion ordinates on the European side (Section §2.5.2) and with the crowdsourced felt intensity data, which show a mean intensity differential of 0.45 units between the European and Asian sides (Section §7.4.1). The correspondence between higher recorded PGA values, higher felt intensities and higher damage report concentrations on the European side is consistent with the prevalence of softer soil conditions (predominantly ZC and ZD classes) in European-side districts, though a formal site amplification analysis lies beyond the scope of this report.

Table 4: *Six districts generating the highest concentrations of building damage reports following the 23 April 2025 earthquake, ranked by report volume. Of 6,539 reports received across Istanbul, 1,473 buildings were found undamaged and 101 lightly damaged on inspection; 80% of all reports originated from the European side. District-level counts and red/yellow/green tagging data by district had not been published at the time of writing. Dominant building stock characterisation is based on the macroform period analysis in Chapter 3. Source: Kurum (2025b); building stock: Chapter 3; soil conditions: IMM (2020a-f).*

District	Rank	Dominant stock	Soil conditions (Vs30-based)
Bahçelievler (European side)	1st	1955–1975 RC frame	Soft alluvium throughout (ZD–ZE, 150–250 m/s)
Esenler (European side)	2nd	1975–1994 RC frame	Highly variable along the N-S axis; soft alluvium in south (ZE, ~150 m/s), bedrock in north (ZB, ~1400 m/s)
Bağcılar (European side)	3rd	1975–1994 RC frame	Highly variable along the N-S axis; soft alluvium in south (ZE, ~150 m/s), bedrock in north (ZB, ~1400 m/s)
Zeytinburnu (European side)	4th	Pre-1955 and 1955–1975 mixed stock	Soft alluvium throughout (ZD–ZE, 150–250 m/s)
Avcılar (European side)	5th	1975–1994 RC frame	Variable; very soft in south (ZE, ~150 m/s), moderate in north (ZC, up to 600 m/s)
Küçükçekmece (European side)	6th	1955–1975 / 1975–1994 RC frame	Predominantly soft (ZD–ZE); patchy stiffer deposits in north (ZC-B, up to 800 m/s)

These five districts correspond almost exactly to those repeatedly identified as highest-risk in scenario loss studies since 2002 (Chapter 3, Section §3.2). The 2025 damage report geography is not a new finding – it is a confirmation, under real-world moderate loading, of what engineering analysis had already predicted. Its significance lies in the implicit forward implication: The districts generating the most damage reports under recorded ground motions that remained well below DD-2 design levels are the districts that will generate the most collapses in the anticipated Mw 7+ event.

The ESDOF analysis in Chapter 5 identifies Avcılar (Station 3428) as recording both the highest rates of inelastic demand exceedance and the longest strong motion duration (D5-95 up to 40.68 s) of the four analysed stations – a combination that points to compounded structural vulnerability beyond what either metric alone would suggest, and that is consistent with the anomalously high damage rates recorded in the same district during the 1999 Kocaeli and Düzce earthquakes. The persistence of that vulnerability is documented: in 2021 the Mayor of Avcılar publicly confirmed that 199 buildings which had sustained moderate damage in the 1999 earthquake had never been demolished or evacuated, and that the legally granted grace period for their remediation had expired in 2020 (Hürriyet, 2021). These buildings were therefore still standing and occupied on 23 April 2025. That Avcılar does not appear among the five highest damage-report districts in Table 4 may reflect differences in reporting behaviour, building stock age distribution, or the spatial resolution of ministerial inspection data, and warrants specific attention when disaggregated inspection results become available. Three structural incidents were confirmed. In Fatih, a derelict (*metruk*) three-storey unreinforced masonry building collapsed – no casualties as the building was unoccupied (MAR-003, MAR-053). In Bakırköy, a three-storey building partially collapsed. In Büyükçekmece, a building roof was displaced. A four-storey building in Silivri and three buildings in Yalova sustained light structural damage. Critically, social media evidence (MAR-030, MAR-037; MAR-057) documents fractured RC columns in Küçükçekmece containing mussel shells (*midye kabukları*) used as aggregate substitute – a known construction defect that severely compromises compressive strength and reinforcement bond. In one documented case, the building owner applied for a damage assessment and received an SMS response stating there was 'no earthquake-related damage', illustrating how the assessment system can fail to identify structurally significant defects (MAR-057). This is not a minor cosmetic issue: it represents a potentially widespread hidden vulnerability in the pre-1999 stock of a district that recorded one of the highest damage report densities.

Aydoğdu and İlki (2026) conducted a post-event analysis of 38,049 buildings across Istanbul, finding strong correspondence between pre-event PERA2019 risk levels and post-event damage observations – providing a rare real-world validation of a probabilistic risk model. Importantly, they found that non-structural infill walls limited damage during this short-duration (13-second) event. However, the same study further found that buildings showing light damage under the 2025 ground motion record – using the Station 3428 (Avcılar) record as a reference, with a significant duration of 41 s and PGA of 0.10g – would not survive a longer-duration record of comparable PGA. This finding – that the 2025 result is a duration-specific outcome, not an indicator of structural adequacy – is one of the most important engineering conclusions from the event.

Bağcılar Kadın Doğum ve Çocuk Hastalıkları Hastanesi – a seismically isolated hospital that had been officially opened just four days before the earthquake – reportedly sustained damage (MAR-038, Halk TV). The reported cracks appear to be non-structural in nature, affecting finishing and partition elements. However, an effectively isolated building should experience significantly reduced superstructure accelerations, and the extent of non-structural cracking reported in a base-isolated facility under moderate ground shaking warrants scrutiny: it may indicate deficiencies in the detailing of non-structural elements for the expected differential movements at the isolation plane, or raise questions about the performance of the isolation system itself. Detailed inspection findings should be published.

6.3 Heritage and monumental structures

No significant structural damage to designated World Heritage structures or formally listed buildings was officially reported. The Fatih district mayor confirmed no damage within the UNESCO-designated Historic Peninsula precinct. Hagia Sophia Mosque, currently undergoing seismic monitoring and intervention work, was unaffected. The Tünel funicular (line F2, the world's second-oldest underground railway, in operation since 1875) was closed as a precautionary measure but sustained no structural damage (personal observation, 23 April 2025).

Minor structural damage to buildings within the Cerrahpaşa Medical Faculty Hospital complex – a campus of historic buildings of varying periods in Fatih – was observed by the lead author on 23 April 2025 (personal observation). The Istanbul University-Cerrahpaşa preliminary inspection report (İÜC, 2025) confirmed light damage to some structures on the campus. This is significant: Cerrahpaşa is a working hospital and a heritage complex simultaneously, and the interaction between seismic vulnerability and operational continuity warrants specific attention in pre-event risk management.

Four schools were evacuated on structural grounds within a week of the event: Sultanahmet Suphi Paşa Mesleki ve Teknik Anadolu Lisesi (Fatih), Fatih Katip Çelebi İlkokulu, Silivri Gazi İmam Hatip Ortaokulu, and the preschool building of Üsküdar Halil Rüştü İlkokulu. The Education Minister's public statement on 23 April that 'none of our schools have any issues' was followed within one week by the announcement that four schools had been evacuated on structural grounds – three of them characterised as 'historic buildings with pre-existing problems.' The week-long gap between official reassurance and the revelation of structural risk allowed misinformation about school safety to circulate on social media. This communication failure is discussed in the governance section of Chapter 9. A separate statement by Istanbul Governor Davut Gül, also issued in the days following the earthquake, similarly asserted that no damage had occurred in any Istanbul schools – a claim contradicted within days by the same evacuation announcements (MAR-056).

The broader significance is that Istanbul holds the largest stock of pre-1900 masonry buildings in the Marmara Region, concentrated in the Historic Peninsula (Fatih, Eminönü, Beyoğlu). These buildings were not designed for seismic loading; their performance in a Mw 7+ event is a major concern both for life safety and for the irreplaceable cultural heritage they represent.

6.4 Lifelines and critical infrastructure

No major lifeline failures were observed. The Istanbul Earthquake Rapid Response and Early Warning System (IERREWS) and the IGDAŞ natural-gas automatic shut-off network (IGRAS) both triggered correctly and performed as designed (Erdik et al., 2025). Eight base-isolated hospitals remained fully operational throughout the event and its aftershock sequence, reflecting the mandatory seismic isolation requirements introduced in 2013 for hospitals with capacities exceeding 100 beds (Erdik et al., 2018).

Transport infrastructure – airports, Marmaray suburban rail, metro, ferry services, and major road networks – was briefly suspended for safety inspections and then resumed within hours. The Kuzey Marmara Motorway, designated as an emergency logistics corridor in Istanbul's disaster response plan, functioned normally for emergency purposes but experienced significant passenger traffic as residents sought to leave the city on the evening of 23 April (MAR-005). Utilities (gas, water, electricity) were unaffected.

The principal infrastructure failure was mobile telecommunications saturation. Network congestion was documented within minutes of the mainshock across multiple European-side districts (MAR-025, MAR-042), preventing voice and SMS communication for a significant share of the affected population. This failure has been documented after every Turkish earthquake since 1999 and has not been substantively addressed in the 26 years since. TÜDER (Turkish Consumers' Association) president Levent Küçük explicitly recommended that citizens shift to internet-based messaging applications in emergencies, implicitly acknowledging GSM network failure as a default post-earthquake condition (Küçük, speaking to Anadolu Ajansı, 25 April 2025). In a Mw 7+ event, telecommunications failure will not resolve itself within an hour; it will coincide with building collapse, fire, medical emergencies, and mass evacuation simultaneously.

6.5 Conclusions

The three threads of this chapter converge on a consistent picture. Structural damage was light and geographically concentrated on the European side of Istanbul, in the same districts that scenario loss studies have identified as highest-risk since 2002 – confirming the predictive validity of those models under real moderate loading while underscoring how far the anticipated major event exceeds anything the building stock has been tested against. Heritage structures and schools emerged largely undamaged, but the week-long gap between official reassurances about school safety and the subsequent evacuation of four buildings on structural grounds illustrates a pattern of official communication that will carry greater consequences under higher-stakes conditions. Lifeline systems – early warning, gas shut-off, base-isolated hospitals – performed as designed and represent genuine returns on post-1999 investment. The single significant infrastructure failure was mobile telecommunications saturation, a vulnerability documented after every Turkish earthquake since 1999 and still unresolved. Taken together, the built environment impact of the 2025 event is best characterised not by what failed but by what was not tested: recorded ground motions remained well below DD-2 design levels at all stations, strong motion durations ranged from approximately 11 to 41 seconds depending on station and component,, and the result tells us little about its performance under the conditions the anticipated major event will produce.

7. Observed Impact: Societal Response

Chapter summary in plain terms

This chapter documents how Istanbul's population responded to the earthquake – and asks why the response was so much larger than the physical damage would predict. One person died and 359 people were injured, the majority from panic rather than structural failure. The earthquake struck on a public holiday, when many families were already outdoors – reducing entrapment risk but causing large outdoor gatherings to spontaneously convert into informal assembly areas before any official activation. Yet approximately 100,000 people spent at least one night outdoors, bus fares tripled, and rental prices in stable-ground districts rose over 100% within hours. Fear of Earthquake Scale data collected by EMSC in near-real time – the first application of this psychometric instrument to a real-time post-earthquake dataset – show that 42% of respondents were in the high-fear category, consistent with a population that has internalised decades of awareness about Istanbul's seismic risk. Outdoor sheltering was geographically sorted – European-side residents were significantly more likely to remain outside than Asian-side residents, consistent with rational risk perception of their buildings' structural quality. The chapter argues that the scale of the societal response reflects this pre-existing fear baseline rather than the 2025 event alone, and that the behaviour documented here represents not irrational panic but a calibrated population response to a recognised existential risk – a distinction that has direct implications for how emergency communication strategies should be designed.

7.1 Introduction

This chapter documents the societal impact of the 23 April 2025 earthquake – the human consequences in terms of casualties and injuries, the behavioural response of Istanbul's population in the hours and days following the mainshock, and the quantitative evidence on perception of the event and fear response provided by the EMSC crowdsourced datasets. Societal impact is treated as analytically distinct from physical impact: the scale of the response documented here – 100,000 people outdoors overnight, mass exodus attempts, sustained outmigration – cannot be explained by the physical damage alone, and understanding the gap between physical and societal impact is central to assessing Istanbul's preparedness for the major anticipated event.

7.2 Casualties, injuries and population impact

The human cost of the 23 April 2025 earthquake was, in absolute terms, low. One person died – a foreign national who suffered a fatal cardiac arrest attributed to shock. A total of 359 injuries were recorded across the Marmara region: 236 in Istanbul, 40 in Sakarya, 28 in Tekirdağ, 23 in Kocaeli, 21 in Yalova, and 11 in Bursa (İletişim Başkanlığı, 2025; provincial health authority reports as compiled by Turkish media – note that EM-DAT (2026) records 236 injuries for Istanbul province only, reflecting the provincial rather than regional total). Critically, the overwhelming majority of injuries resulted not from structural failure but from panic behaviour – falling from windows and balconies, or falling on stairs during evacuation. The Istanbul Governor's Office reported that 151 of Istanbul's 236 injuries were sustained by people jumping from height due to panic. No injuries were classified as life-threatening (Ministry of Health, 24 April 2025).

The injury geography extends well beyond Istanbul and reflects the wide shaking footprint of the event (see Chapter 2, Figure 9), with all five Marmara provinces recording injuries. The initial official injury figure at 15:30 on 23 April was 151; the consolidated total of 359 reflects reporting over subsequent days as less serious cases were entered into provincial health system records. The gap between the initial and final figures is a useful reminder that post-earthquake casualty data should be treated as evolving rather than fixed in the hours following an event.

The injury profile – dominated by panic response rather than structural failure, though the contribution of non-structural element damage to the injury toll is not fully documented – is consistent with international experience of moderate urban earthquakes. It underscores the public communication imperative: in a population already primed to fear the consequences of earthquakes (documented quantitatively in Section §7.4.2), behavioural injury from panic may rival injury from damage to physical infrastructure even in events where damage levels are moderate or negligible. In a Mw 7+ event where both severe structural damage and/or collapse and panic occur simultaneously, this behavioural dynamic will be far harder to manage.

7.3 Population behaviour and mass evacuation

The societal response to the 23 April earthquake was substantially disproportionate to its physical impact. Approximately 40,000 people sheltered in parks, *millet bahçeleri*, mosques and open spaces on the night of 23–24 April, declining to return to their homes despite the fact that no inhabited buildings collapsed. An estimated 100,000 people in total spent at least one night outdoors across the broader event period (Istanbul Valiliği, 23 April 2025; MAR-024). Schools and universities in Istanbul and Tekirdağ closed for two days. Over 500,000 portions of soup and one million water and food packages were distributed from 348 distribution points across the city (Turkish Red Crescent, 2025).

The earthquake struck at 12:49 on a public holiday (23 Nisan, National Sovereignty and Children's Day), when many families were already outdoors. This timing reduced entrapment risk but created large gatherings in urban open areas that spontaneously converted to informal assembly points (MAR-002, MAR-004, MAR-021). As the afternoon progressed, social media documentation captured a rapid and widespread decision to remain outdoors rather than re-enter buildings – driven not by confirmed structural damage to their own buildings but by seismic risk perception and fear. The Fear of Earthquake Scale data (Section §7.4.2) provide quantitative evidence of this elevated fear baseline.

A significant exodus from the city was also documented. Social media evidence (MAR-005) records the Kuzey Marmara Motorway experiencing heavy congestion on the evening of 23 April as residents drove out of Istanbul. Bus ticket prices tripled within hours (Section §8.2). This population movement pattern – a large fraction of the city attempting to leave simultaneously after a moderate earthquake – has direct implications for emergency logistics planning. In a Mw 7+ event, with actual structural damage, road damage in some districts, and a far larger displaced population, managing this outbound movement alongside incoming emergency response is a challenge that current planning does not address.

The geographic concentration of outdoor sheltering closely mirrored the damage report geography: people in European-side districts with older, more vulnerable building stock were more likely to decline to re-enter their buildings than those in Asian-side districts (MAR-007, MAR-008, MAR-009, MAR-033). This spatial sorting is not random – it reflects a population making rational risk assessments, however imprecise, about their buildings' structural adequacy. Istanbul Valiliği confirmed that school courtyards, sports halls and mosques had been opened for citizens who did not wish to remain in their homes (Istanbul Valiliği, 23 April 2025; MAR-024).

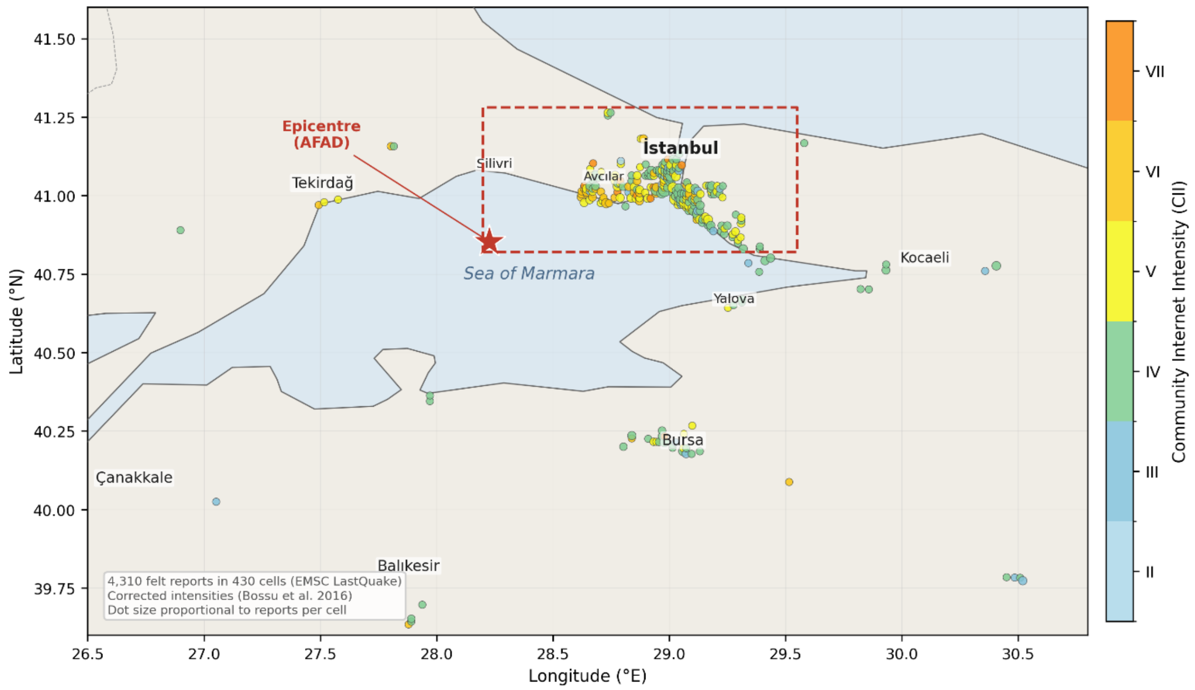
7.4 Crowdsourced shaking perception and fear response: EMSC data

Three datasets were provided by the European-Mediterranean Seismological Centre (EMSC) for this event (event ID 1798415) following a data sharing request by the lead author. These comprise felt intensity reports, Fear of Earthquake Scale (FES) responses, and geolocated photo and video metadata. They complement the instrumental ground motion dataset (Chapter 2) and the social media evidence log (Annex A) with structured crowdsourced data, and are used here with EMSC's permission (Bossu, pers. comm., May 2026).

7.4.1 Felt intensity reports

The EMSC felt report database contains 4,302 individual testimonies for this event, submitted via the EMSC smartphone app (2,158, 50%), mobile web browser (1,549, 36%), desktop browser (582, 14%) and Telegram bot (13, <1%). The temporal distribution is striking: 1,546 reports (36%) were submitted within 10 minutes of the mainshock; 2,744 (64%) within 30 minutes; 3,193 (74%) within one hour – sustained during mobile network saturation documented across European-side districts (Section §5.4; MAR-025, MAR-042). This confirms the utility of crowdsourced app-based reporting as a real-time situational awareness channel that remains active even when voice and SMS networks are congested.

Geographic spread covers 36.9°N-45.8°N and 19.3°E-37.3°E, encompassing Türkiye, Greece, Bulgaria and parts of the Balkans (Figure 21). Within the Istanbul metropolitan area, 1,720 reports were received (40% of total), divided near-equally between the European side (867 reports, mean intensity 4.42) and the Asian side (853 reports, mean intensity 3.97). The 0.45 intensity-unit differential is consistent with the instrumental PGA distribution (Section §2.5.2), the official building damage report geography (80% European-side), and the soft alluvial site conditions (predominantly ZC and ZD soil classes) in the European-side districts most affected – particularly the Küçükçekmece-Bahçelievler-Bağcılar corridor, where low Vs30 values and shallow alluvial deposits are well documented. This crowdsourced corroboration – derived entirely independently of the instrumental and official datasets – substantially strengthens confidence in all three evidence streams simultaneously.



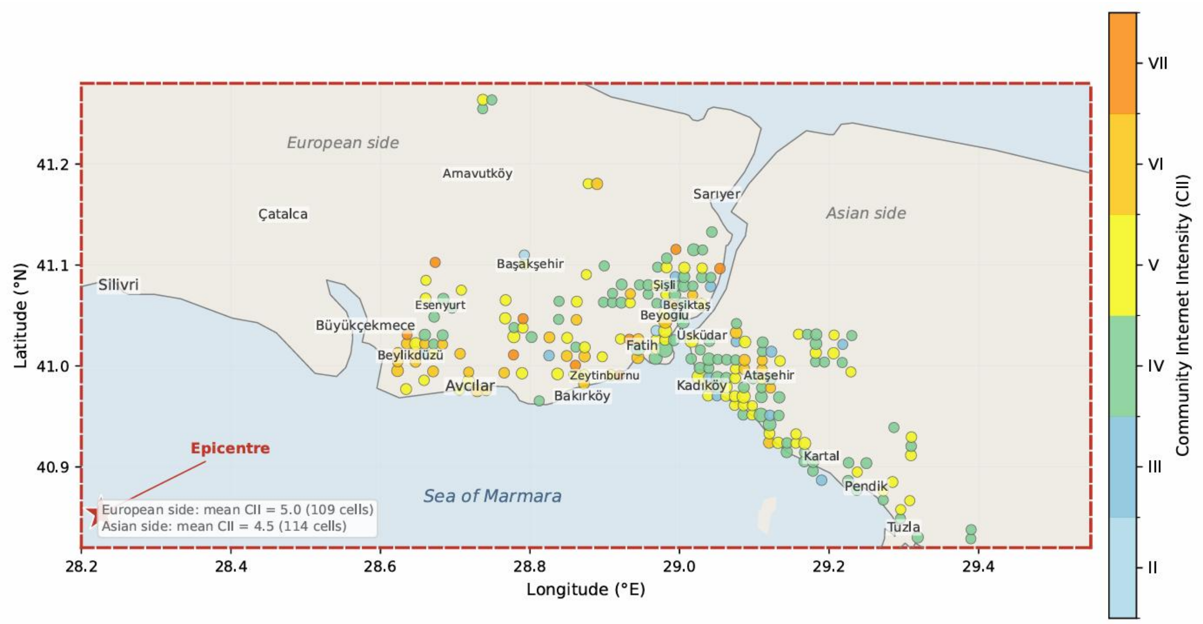


Figure 21: ***(top)*** *Spatial distribution of crowdsourced felt intensity reports for the MW 6.2 Western Marmara Sea earthquake of 23 April 2025, based on 4,310 reports aggregated into 430 1 km × 1 km cells (EMSC LastQuake platform; intensities corrected following Bossu et al. 2016). Dot size is proportional to the number of reports per cell. Community Internet Intensities reach VII in cells on Istanbul's European side (Avcılar, Küçükçekmece, Bakırköy), consistent with both the higher instrumental PGA values recorded at European-side strong-motion stations (Figure 9) and the concentration of building damage reports in these districts (§6.1). Lower intensities (II–III) extend to Tekirdağ, Bursa and Kocaeli. The pronounced European-side intensity concentration corroborates the site-amplification pattern discussed in Chapter 5. Star marks the AFAD-reported epicentre (40.854°N, 28.226°E). Data courtesy of EMSC (R. Bossu, S. Issartel and R. Steed, personal communication, May 2026).* ***(bottom)*** *Istanbul detail of the EMSC felt intensity distribution. The European side (west of the Bosphorus) shows systematically higher Community Internet Intensities (mean CII = 5.0, 109 cells) than the Asian side (mean CII = 4.5, 114 cells), with the highest intensities (VI–VII) concentrated in the coastal districts of Avcılar, Büyükçekmece, Bakırköy and Zeytinburnu. This pattern is consistent with both the higher instrumental PGA values at European-side strong-motion stations (§5) and the predominance of ZC/ZD site classes in these districts. The Asian side shows a secondary cluster of elevated intensities (IV–V) along the Kadıköy–Pendik–Tuzla coastal strip.*

The intensity distribution (Table 5) is modal at I=3 (35%), with intensities I≥6 accounting for 303 reports (7%), concentrated in European-side districts. Of the 4,302 reports, 1,070 (25%) include free-text comments, approximately 478 in Turkish. Among the 87 comments at intensity I≥6, shaking is consistently described as strong, frightening, and sustained, with furniture displacement, falling objects, and immediate evacuation to outdoor areas. Several respondents describe perceived durations of 20–30 seconds, consistent with the 13-second mainshock followed by early aftershocks. One respondent directly compared the 23 April shaking to their experience of the 1999 Kocaeli earthquake, describing the 2025 event as similar in perceived intensity but shorter in duration – consistent with the shorter ground motion record – and noting that their building, renovated in 2015, appeared to have performed comparably (MAR-073).

Table 5: *Distribution of EMSC felt report intensities for the 23 April 2025 Marmara Sea earthquake (event 1798415, n=4,302). Source: EMSC (Bossu, Issartel and Steed, pers. comm., May 2026).*

EMSC Intensity	**I=1**	**I=2**	**I=3**	**I=4**	**I=5**	**I=6**	**I=7**	**I=8-9**
Reports (n)	135	622	1,497	1,116	629	226	44	33

Share (%)	3	14	35	26	15	5	1	<1

7.4.2 Fear of Earthquake Scale responses

As a pilot project, EMSC integrated the Fear of Earthquake Scale (FES; Sarı et al., 2023) into their reporting platform for this event. The FES is a validated 7-item psychometric instrument developed following the 2023 Kahramanmaraş earthquake sequence, measuring emotional and somatic fear responses on a 1–5 Likert scale per item (total 7–35; Cronbach's α=0.89 overall; 0.84 emotional subscale; 0.86 somatic subscale). The dataset contains 186 complete responses collected in near-real time, with approximately 93 (50%) from within the Istanbul metropolitan area. This represents, to the authors' knowledge, the first application of the FES to real-time data collected within hours of an earthquake rather than in a subsequent survey. The geographic concentration of responses within Istanbul is consistent with the spatial distribution of the felt intensity data (Section §7.4.1), in which European-side districts recorded systematically higher mean intensities – suggesting that the highest fear responses may reflect both pre-existing baseline fear and elevated shaking experience, though the dataset is insufficient to disaggregate these effects.

Mean total FES score: 22.60/35 (mean per-item score 3.23/5), substantially above the scale midpoint of 21. High fear (>24): 42% of respondents (n=78). Moderate (15–24): 39% (n=72). Low (<15): 19% (n=36). Median: 22.0. Per-item means are shown in Table 6, together with the item labels.

Table 6: *Per-item mean FES scores (1-5 Likert scale, n=186 respondents) for the 23 April 2025 Marmara Sea earthquake. Source: EMSC (Bossu, pers. comm., May 2026); FES instrument: Sarı et al. (2023).*

Item	Label	Mean (1–5)
FE1	I am very fearful about earthquakes	3.62
FE2	Thinking about earthquakes disturbs me	3.60
FE3	My hands shake when I think about the earthquake	2.47
FE4	I am very afraid of losing my life in an earthquake	3.42
FE5	I get anxious and worried when I watch news and stories about earthquakes in the media	3.28
FE6	Worry about being caught in an earthquake keeps me awake	2.96
FE7	My heartbeat speeds up when I think about being caught in an earthquake	3.25

The per-item pattern is analytically informative. The highest-scoring items – FE1 (3.62), FE2 (3.60), FE4 (3.42) and FE7 (3.25) – all capture direct existential fear: general earthquake fear, cognitive disturbance, fear of death, and acute physiological arousal. The lowest-scoring item is FE3 (2.47), which measures overt somatic response (shaking hands), and FE6 (2.96), which captures chronic sleep disruption from earthquake worry. The pattern is consistent with a population that has cognitively internalised earthquake as an existential threat and responds with elevated acute fear when the threat becomes real, but which does not exist in a constant state of somatic hyperarousal or chronic sleep disruption in the absence of shaking.

The headline finding is analytically significant. A mean FES score of 22.60/35 with 42% of respondents in the high-fear range was generated by an earthquake that caused one fatality and only light structural damage. The FES was developed in the context of the 2023 Kahramanmaraş sequence, which killed over 50,000 people – yet fear scores recorded here, for an incomparably less destructive event, are high. This is consistent with a chronically elevated fear baseline in Istanbul's population, accumulated through decades of awareness of the seismic gap and amplified by the 2023 events. The FES data provide the first quantitative psychometric evidence for this proposition: that the behavioural responses documented in §7.3 – 100,000 people outdoors overnight despite no structural collapses, housing market surges within hours, sustained outmigration – represent not a disproportionate reaction to a moderate event but a calibrated response to a widely recognised existential risk that the 2025 earthquake made newly vivid. The same caveat applies with greater force to the FES dataset: at n = 186, drawn from LastQuake users who chose to complete a psychometric instrument in the immediate aftermath of the event, the sample is small, self-selected and non-probabilistic, and is likely biased toward more engaged – and plausibly more fearful – respondents. The FES results should therefore be read as characterising the fear profile of the app-using, report-submitting population rather than of Istanbul's population at large, and the 42% high-fear share should not be extrapolated citywide.

7.4.3 Geolocated photo and video documentation

EMSC also provided the metadata file for user-submitted geolocated photos and videos associated with this event (picquest_1798415.csv). This contains GPS coordinates, timestamps and filenames for 25 files (17 images, 8 videos), the first of which was submitted 11 minutes after the mainshock, with 20 of 25 (80%) submitted within 24 hours. Geographic distribution is concentrated in the Istanbul–Tekirdağ corridor. The actual image and video files were not available to the authors at the time of writing. The metadata alone nonetheless confirms the pattern of immediate digital engagement documented in the felt report data: within 11 minutes of the mainshock, residents were already geotagging and submitting visual documentation of the event through structured platforms, in parallel with the 1,546 felt intensity reports submitted in the same window.

7.5. Conclusions

The three components of this chapter point toward a single finding. The injury profile – dominated by panic-driven falls rather than structural failure – indicates that behavioural response injuries may rival injuries caused by damage to physical infrastructure in populations with elevated seismic fear baselines. The population behaviour data – 100,000 outdoors, mass departure attempts, geographic sorting of sheltering by perceived building vulnerability – is consistent with a population responding to decades of accumulated seismic risk awareness rather than to the physical impact of this specific event. The FES data quantify this baseline for the first time in a real-time post-earthquake context: a mean score of 22.60/35 with 42% of respondents in the high-fear range, generated by an earthquake that caused one structural fatality, indicates that the threshold for large-scale behavioural response in Istanbul is substantially lower than the physical damage level. This has direct implications for emergency planning: models of post-earthquake population behaviour calibrated to physical damage alone will systematically underestimate the scale of displacement, evacuation and communication demand that even a moderate event will generate. The integration of crowdsourced felt intensity data, social media sentiment and psychometric fear measures used in this report builds on prior work applying intensity-based analysis to societal response, including after the 2020 Aegean earthquake, where similar EMSC crowdsourced data were used to characterise the relationship between shaking intensity, sentiment and topic patterns in near-real-time social media (Contreras et al., 2022; Aktas et al., 2021; 2022), and points toward a methodological framework for future post-earthquake societal impact assessment that does not rely solely on physical damage metrics.

8. Observed Impact: Economic Repercussions

Chapter summary in plain terms

This chapter documents two economic consequences of the 2025 earthquake that reveal structural vulnerabilities in Istanbul's financial protection framework. The housing market sorted by perceived seismic safety within hours: rental prices in stable-ground districts rose by over 100% and bus ticket prices on routes out of Istanbul tripled simultaneously – labelled *deprem fırsatçılığı* (earthquake opportunism) by the Turkish Consumers' Association, with the Ministry of Trade fining 58 landlords a total of 14.5 million TL within 48 hours of the mainshock. This pattern is consistent with sustained seismic-risk-driven outmigration from Istanbul of approximately 950,000 people over 2023–2024. In the absence of effective market interventions, these dynamics will progressively price lower-income households out of the safest housing stock and into the most vulnerable buildings in the highest-risk districts – concentrating exposure in the population least protected by other risk-reduction programmes.

The compulsory earthquake insurance system, DASK, paid out as little as 6,400 TL for multi-room damage – near-zero after deductibles in multiple documented cases. The deductible mechanism is structural: for a standard flat, a repair bill must substantially exceed approximately 6,000 TL before any net payout is generated, meaning DASK provides negligible protection against the light-to-moderate damage that a sub-Mw 7 event produces. Coverage ceilings have not kept pace with Istanbul's post-2020 construction inflation, and institutional failures – including failure to alert policyholders to underinsurance – compound the structural inadequacy. These failures were documented in four successive moderate earthquakes since 2020 without substantive reform; in the 2023 Kahramanmaraş sequence, DASK paid approximately 147,000 TL for a completely destroyed dwelling and then sought to claw back 75,000 TL of that amount.

Both failures share a common governance structure: nominal financial protection frameworks, designed in good faith after the 1999 earthquake, progressively eroded or left unupdated. Both are politically tractable – they require regulatory decisions, not engineering breakthroughs – and both have been identified in previous post-earthquake assessments without triggering reform. In a major event, the same mechanisms will leave hundreds of thousands of households without meaningful financial protection at precisely the moment they need it most.

8.1 Introduction

This chapter documents two economic dimensions of the 23 April 2025 event that are analytically distinct from the physical and societal impacts covered in Chapters 5 and 6, but that share a common diagnostic significance: both the housing market response and the DASK insurance system failure reveal the gap between the nominal financial protection Istanbul's population believes it has and the actual protection available when tested at moderate earthquake scale. Neither finding is new – both have been documented after previous moderate Turkish earthquakes. Their persistence makes them more significant, not less.

8.2 Market shock and price exploitation

Within hours of the mainshock, the Turkish Consumers' Association (TÜDER) documented systematic price exploitation across two markets simultaneously. Rental and sale prices in districts with stable ground conditions ('sağlam zeminli bölgeler') rose by over 100%, as residents sought to relocate away from perceived high-risk European-side stock (MAR-060). Bus ticket prices tripled on routes out of Istanbul as residents attempted to leave the city. TÜDER president Levent Küçük characterised the pattern explicitly as 'deprem fırsatçılığı' – earthquake opportunism – and called on the Ministry of Trade to enforce price controls (Küçük, TÜDER, speaking to Anadolu Ajansı, 25 April 2025).

The Ministry of Trade responded by fining 58 landlords and agents a total of 14.5 million TL (250,000 TL per violation) (Ministry of Trade, press statement, 25 April 2025). The speed of enforcement – within 24–48 hours of the mainshock – confirms that the price manipulation was both rapid and widespread enough to trigger regulatory action. Küçük also reported GSM operator complaints regarding network saturation, recommending users shift to internet-based applications in emergencies, consistent with the telecommunications failure documented in §5.4.

The geographic pattern of the price surge is analytically significant. Prices rose most sharply in stable-ground districts without softer soils – a spatial signal that Istanbul's population has internalised seismic risk as a permanent, real-time pricing variable. The housing market sorted by perceived seismic safety within hours of the mainshock. This is consistent with post-earthquake outmigration data showing that 581,000 people left Istanbul for other provinces in 2023 and 369,000 in 2024 – approximately 950,000 in two years (TÜİK, 2025) – and with rental price analyses showing continued appreciation in perceived low-risk peripheral districts such as Silivri. It implies that in the absence of interventions – whether regulatory, insurance-based, or structural – market forces will progressively price lower-income households out of the safest housing and into the most vulnerable stock in the highest-risk districts.

The bus ticket tripling has an additional dimension: it reveals a population actively trying to flee the city in the event of a moderate shock. In a major earthquake, the same dynamics – mass departure attempt, transport network collapse, price gouging – would be catastrophic for the city's emergency logistics and post-event coordination.

8.3 DASK earthquake insurance: structural failure at moderate scale

DASK (*Doğal Afet Sigortaları Kurumu*) is Türkiye's compulsory earthquake insurance pool, established after the 1999 İzmit earthquake. It covers structural elements of registered dwellings – foundations, main walls, floors, roofs, staircases – against earthquake and earthquake-triggered secondary hazards, within limits set annually by the Ministry of Treasury and Finance. DASK is not optional: it is legally required for all titled residential properties within municipal boundaries, and voluntary supplementary cover is permitted only where DASK has been activated first (DASK, 2024).

Consumer complaints filed on the Şikayetvar platform following 23 April reveal a systematic pattern of inadequate payouts for the light damage category this event produced. Documented cases include:

- A policyholder in Arnavutköy whose flat sustained cracks and tile damage across all rooms: DASK payout 6,400 TL – insufficient to cover even basic labour costs (Şikayetvar, April 2025).
- A policyholder whose tiles were destroyed and bedroom sustained a floor-to-ceiling crack received a DASK settlement of 3,000 TL; the supplementary insurer stated DASK must be exhausted first, rendering the combined cover meaningless at this damage level (MAR-067).
- A policyholder whose claim was almost entirely consumed by the deductible (muafiyet), resulting in a near-zero net payment (Şikayetvar, April 2025).
- A Büyükçekmece case where DASK's own hasar file (number 2500011818) confirmed deep cracks in columns, slabs and beams, with Büyükçekmece municipality engineers classifying the building as dangerous – yet the DASK settlement remained contested (Şikayetvar, April 2025).

- A DASK adjuster declared damage 'not from earthquake, but from aging' and refused to pay, despite visible damage and a valid policy: 'There is a policy, there is damage, but no money. What is the point of insurance in this country?' (MAR-072).

The structural reason for this pattern is well understood. DASK's deductible mechanism operates on a percentage-of-building-value basis: for a 100 m² flat at current cost rates, the deductible threshold (tenzil muafiyeti) is approximately 6,032 TL. A repair bill of 6,035 TL generates a net DASK payout of 3 TL. A 10,000 TL repair bill generates a payout of approximately 3,965 TL. The instrument is designed to absorb catastrophic total-loss or near-total-loss events; it provides negligible financial protection for the light-damage category – cracks, plaster failure, tile loss, minor structural cracking – that constitutes the vast majority of damage in a moderate urban earthquake (Şikayetvar, April–May 2025).

The coverage ceiling problem compounds this. DASK's maximum insured value is set at 2,220,218 TL (as of January 2024), calculated as the product of floor area and a Ministry-set unit construction cost of 10,473 TL/m² (DASK, 2024). For a 75 m² flat this yields a maximum insured value of approximately 785,475 TL – a figure that reflects construction replacement cost, not market value, and that has not kept pace with Istanbul's extreme post-2020 construction inflation. One complainant noted that for their 75 m² flat the coverage limit was 226,000 TL – a figure they recognised as self-evidently insufficient even before any damage occurred (Şikayetvar, April 2025).

A documented pattern of institutional management failures reinforces this structural inadequacy: DASK failed to communicate tariff changes correctly to policyholders, failed to proactively alert holders when their policies became underinsured, and has maintained the same unresolved procedural problems across successive moderate events – Elazığ 2020, İzmir 2020, Düzce 2022, and now the 2025 Marmara Sea earthquake. The result is a compulsory insurance system that collects premiums from millions of Istanbul residents but does not provide meaningful financial protection against the light-to-moderate damage that a sub-Mw 7 event actually produces – which is precisely the damage category most likely to recur before the anticipated major rupture. It is important to note that this coverage structure may reflect a deliberate actuarial design choice rather than an oversight: catastrophic earthquake insurance products – including the California Earthquake Authority (CEA) model – typically employ high deductibles and exclude light damage precisely to preserve fund solvency for the major event. The question for DASK is therefore not only whether the coverage level is appropriate, but whether policyholders understand what they are and are not covered for, and whether the compulsory nature of the product creates an expectation of protection that the product design does not deliver.

In a Mw 7+ event, these failures compound catastrophically. DASK's reinsurance arrangements are designed to cover large aggregate claims, but the per-unit payout inadequacy means that even households with valid policies will face an overwhelming gap between insurance receipts and repair or rebuilding costs. The 2023 Kahramanmaraş sequence, in which DASK paid approximately 147,000 TL to one Hatay policyholder for a completely destroyed dwelling and then sought to claw back 75,000 TL of that amount, illustrates the human consequence of this gap at full catastrophe scale (Şikayetvar, 2023; TMMOB, 2023).

8.4 Conclusions

The two failures documented in this chapter – housing market exploitation and DASK inadequacy – are analytically distinct but share a common governance structure. That successive moderate earthquakes since 2020 have exposed the same DASK deficiencies without triggering substantive reform underscores the institutional inertia that characterises this governance space. In both cases, an institutional framework nominally designed to protect Istanbul's population against earthquake has been allowed to fall systematically short of its purpose: one through the absence of effective price controls during emergency conditions, the other through failure to maintain adequate coverage levels against inflation and construction cost escalation. The DASK failure is a direct parallel to the assembly area erosion documented in Chapter 9: in all three cases, the protective infrastructure exists on paper, was designed in good faith after a major disaster, and has been progressively eroded or left unupdated in the years since. All three failures are politically tractable – they require regulatory decisions, not engineering breakthroughs. All three have been identified in previous post-earthquake assessments and remain unresolved by the relevant regulatory and planning authorities. The 2025 event thus serves not only as a stress test of Istanbul's physical infrastructure but as an audit of its financial and institutional protective frameworks – an audit that both failed at moderate scale and that will face far greater demands when the major anticipated event occurs.

9. Disaster Assembly Areas and Urban Preparedness

Chapter summary in plain terms

This chapter examines Istanbul's system of designated disaster assembly areas and assesses its real-world performance on the night of 23 April 2025. The system has been progressively eroded since it was established after the 1999 earthquake: 419 of 496 post-1999 designated areas have been converted to commercial development, including 95 that became shopping malls – some of whose forecourts and car parks are now re-designated as the replacement assembly areas. The average per-capita provision across Istanbul is 2.98 m², below the Sphere Project's recommended minimum of 3.5 m², with the worst provision concentrated in Bahçelievler, Gaziosmanpaşa, Bağcılar and Sancaktepe – the same districts with the oldest and most vulnerable building stock. On the night of 23 April, with approximately 100,000 people needing outdoor space after an earthquake that caused no structural collapse, the system failed operationally: Gezi Parkı was blocked by police preventing entry to a formally designated area; residents in Bağcılar spent the night on the highway for lack of any accessible assembly point; gates were locked, construction sites occupied designated plots, and at least one district had no functional capacity whatsoever. Critically, none of these failures was caused by the earthquake – all were pre-existing, knowable conditions that an operational audit would have identified. Three positive cases are also documented; in each, what worked was either a purpose-designed open space with adequate area and management infrastructure, or spontaneous community appropriation of genuinely accessible public space, not the officially designated but operationally dysfunctional areas the formal system provides. The chapter concludes that the assembly area system failed under the most favourable possible conditions and will not cope with the demands of the anticipated major event.

9.1 Background and system status

Istanbul's assembly area system has its origins in the aftermath of the 1999 Marmara earthquake, which exposed the absence of designated safe gathering spaces as a critical gap in the city's emergency response capacity. In the years that followed, disaster management policies underwent major transformations: assembly areas were formally defined as initial meeting points after a disaster and incorporated into planning processes at both central and local levels. However, despite the time that has passed, issues such as the number of these areas, their accessibility and their protection remain highly relevant. Under pressures of urban growth and development, the functionality of these spaces has been progressively weakened – and the 23 April 2025 earthquake brought these long-standing deficiencies back into sharp public focus. Despite the growing importance of disaster assembly areas, in Istanbul their number and functionality face significant challenges. It is well-known that some of the assembly areas designated after the 1999 Marmara Earthquake were opened to development over the years through planning amendments, and many of them have since been transformed into shopping malls, hotels or high-density housing projects. Research conducted by professional bodies–particularly the Union of Chambers of Turkish Engineers and Architects (TMMOB)–shows that publicly accessible green spaces have decreased, and some of the designated assembly areas have become practically unusable. In this context, data released by the Chamber of Civil Engineers (İMO) indicate that of the approximately 496 areas designated as disaster assembly zones in Istanbul after the 1999 earthquake, 419 were opened to development and converted into shopping centres, plazas or business complexes (Kale, 2019)[3].

Following these statements regarding assembly areas, official announcements made by the Disaster and Emergency Management Authority (AFAD) indicate that, as of 2020, there are 3,021 designated assembly areas in Istanbul. AFAD also states that the average assembly area per capita across the province is 1.29 m^2, and that efforts are underway to increase this figure above 2 m^2 and to improve the overall quality of these spaces (AFAD, 2020).

AFAD's district-level assessments further report that Kadıköy has 70 assembly areas, with the per-capita space increasing from 0.94 m^2 to 1.87 m^2; Şişli has 41 assembly areas, with per-capita space increasing from 0.94 m^2 to 1.16 m^2; and in Beşiktaş, the per-capita space has risen from 4.56 m^2 to 5.2 m^2, with the number of assembly areas increased to 62. The announcement also emphasises that these efforts are being carried out under the coordination of the General Command of the Gendarmerie, in collaboration with municipalities, district governorships, neighbourhood administrations (muhtarlıklar), and other relevant institutions and organisations.

In the report titled "Kamusal Olanın Dönüşümü: Alışveriş Merkezlerinin Kentsel Etkileri Üzerine Değerlendirme" (The Transformation of the Public Realm: An Evaluation of the Urban Impacts of Shopping Malls), published by the Istanbul Planning Agency in 2024, it is highlighted that a total of 95 shopping malls located across various districts of the city were built on plots previously designated as earthquake assembly areas. The report emphasises that these plots have a combined area exceeding 20,000 m^2 and could have accommodated approximately 42,200 people in need of shelter following an earthquake (IPA, 2024).

An examination of these assembly areas and the transformations they have undergone over time reveals that: Cumhuriyet Park was privatised and converted into the Akmerkez shopping mall (1993); the area previously used as a bus terminal was transformed into Cevahir Shopping Mall (2005); the former İETT garage became Kanyon Shopping Mall (2006); the former Fire Brigade Square was replaced by City's Nişantaşı Shopping Mall (Figure 22); the large plot owned by the General Directorate of Highways was redeveloped into Zorlu Center (Figure 23); the land of the Mecidiyeköy Military Recruitment Office was converted into Astoria Shopping Mall (2014); the former Ford Otosan Factory site became Akasya Shopping Mall (Figure 24); and the plot where the former Ali Sami Yen Stadium stood was redeveloped into Torun Center (Figure 25).

These transformations reveal not only the spatial loss of public open areas but also the emergence of a significant vulnerability in society's capacity for disaster preparedness. The same green and open spaces that serve as post-earthquake assembly areas also provide critical climate adaptation functions – urban cooling, stormwater absorption and heat island mitigation – meaning their loss compounds vulnerability across multiple hazard types in a city facing both seismic and climate risk. For the areas mentioned, comparative visuals generated using Google Earth images are presented to illustrate their condition when they were designated as assembly areas versus their post-development state. These images clearly demonstrate the spatial transformations these sites have undergone over time, as well as the shift from public to private use.

[3] The Ministry cited 5,500 assembly areas and 3.9 m^2 per capita across Istanbul in April 2025 (Kurum, 2025b); Kurum himself noted this required increase. The higher area count reflects a broader ministerial definition encompassing millet bahçeleri and informal open spaces alongside formally designated emergency assembly points. The 496-area figure used in this report refers specifically to emergency assembly zones formally designated after 1999, as recorded by İMO (Kale, 2019). Both figures fall at or near the Sphere Project minimum of 3.5 m^2 per person.

DESIGNATED ASSEMBLY FUNCTION	CURRENT REDEVELOPMENT
Fire Brigade Square Post-1999 emergency assembly designation	**City's Nişantaşı Shopping Mall** Former assembly function lost after redevelopment

Figure 22: *Spatial transformation of the former Fire Brigade Square → City's Nişantaşı Shopping Mall.*

DESIGNATED ASSEMBLY FUNCTION	CURRENT REDEVELOPMENT
KGM Highways Depot Post-1999 emergency assembly designation	**Zorlu Center** Former assembly function lost after redevelopment

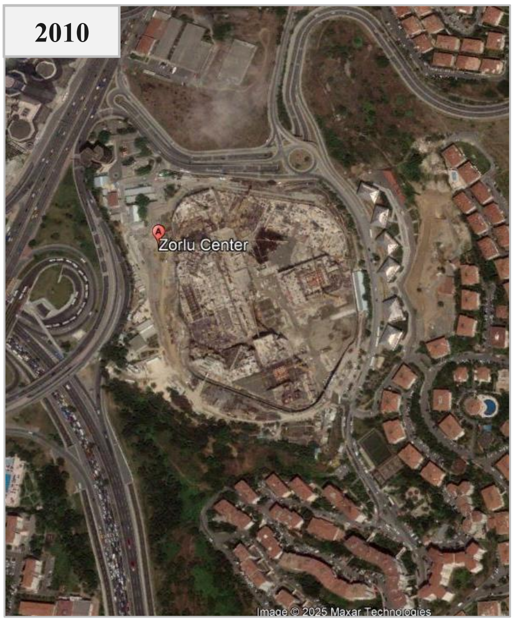
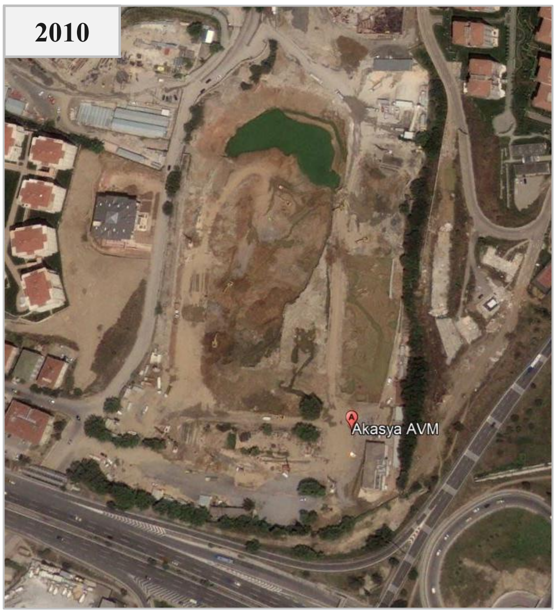


Figure 23: *Spatial transformation of the General Directorate of Highways (KGM) site → Zorlu Center.*

DESIGNATED ASSEMBLY FUNCTION

Ford Otosan Factory Site

Post-1999 emergency assembly designation



CURRENT REDEVELOPMENT

Akasya Shopping Mall

Former assembly function lost after redevelopment

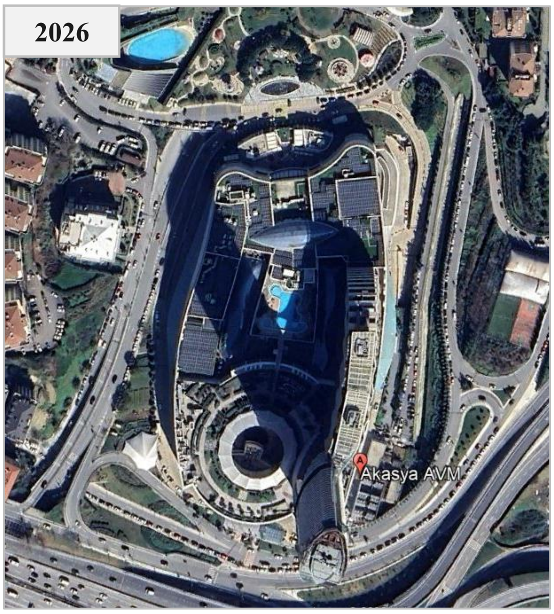


Figure 24: *Spatial transformation of the former Ford Otosan factory site → Akasya Shopping Mall.*

DESIGNATED ASSEMBLY FUNCTION

Ali Sami Yen Stadium Site

Post-1999 emergency assembly designation

CURRENT REDEVELOPMENT

Torun Center

Former assembly function lost after redevelopment

Figure 25: *Spatial transformation of the former Ali Sami Yen Stadium site → Torun Center.*

In Istanbul, official assembly areas have been designated to ensure that citizens can gather safely after a potential earthquake or disaster. These areas, defined through coordination between the Disaster and Emergency Management Authority (AFAD) and relevant municipalities, are typically selected from parks, schoolyards, large squares and other accessible open spaces with low structural risk. Spatial data on post-disaster assembly and temporary shelter areas across Istanbul can be viewed through the IMM City Map, and this map is used as one of the primary data sources for examining the distribution of these areas within the city (IMM City Map, 2025). In addition, district municipalities and district governorates publish lists of designated assembly areas on their official websites, providing complementary local-level information. Moreover, citizens can easily find the nearest assembly area to their location through the "Disaster and Emergency Assembly Area Inquiry" service available on the e-Government platform (e-Devlet, 2025).

Immediately after the earthquake that struck Istanbul on 23 April 2025, a report published by an official news source announced, based on AFAD data, that there are approximately 3,000 disaster assembly areas across Istanbul (Yücel, 2025).

In this context, we initiated a study to assess the current status of disaster assembly areas in Istanbul and to conduct a series of spatial analyses. For this purpose, data from the Istanbul Metropolitan Municipality (IMM), the Disaster and Emergency Management Authority (AFAD) published through the e-Government platform, as well as data released by district municipalities and district governorships, were examined collectively. As of May 2025, it was identified that the number of disaster assembly areas had risen to over 5,500, indicating that new areas were designated immediately after the earthquake. Using these datasets, the study carried out digital mapping and evaluation of disaster assembly areas based on criteria such as spatial distribution, accessibility and per-capita area availability.

The analysis revealed a total of 5,570 disaster assembly areas across Istanbul. The majority of these – approximately 59% – consist of recreational areas. These spaces, defined as parks, gardens and other green areas, stand out as the most suitable locations for rapid and safe gathering during a disaster. Educational institutions make up around 22% of the assembly areas; the open spaces of schools and universities serve as important gathering points in emergencies. The "other areas" category represents 8.9% of the total number of sites, while its share in total area reaches 15.7%, suggesting that these sites tend to be larger and more heterogeneous in character. This category includes residential complex gardens, boulevards, vacant plots and undeveloped lands, open spaces in front of buildings, shopping mall gardens and roadside rest areas. Official institutions and facilities account for roughly 4.6% and play critical roles in post-disaster coordination and management activities. Religious facilities, healthcare facilities, sports areas and similar sites constitute smaller but complementary components of the overall assembly area system (Figure 26).

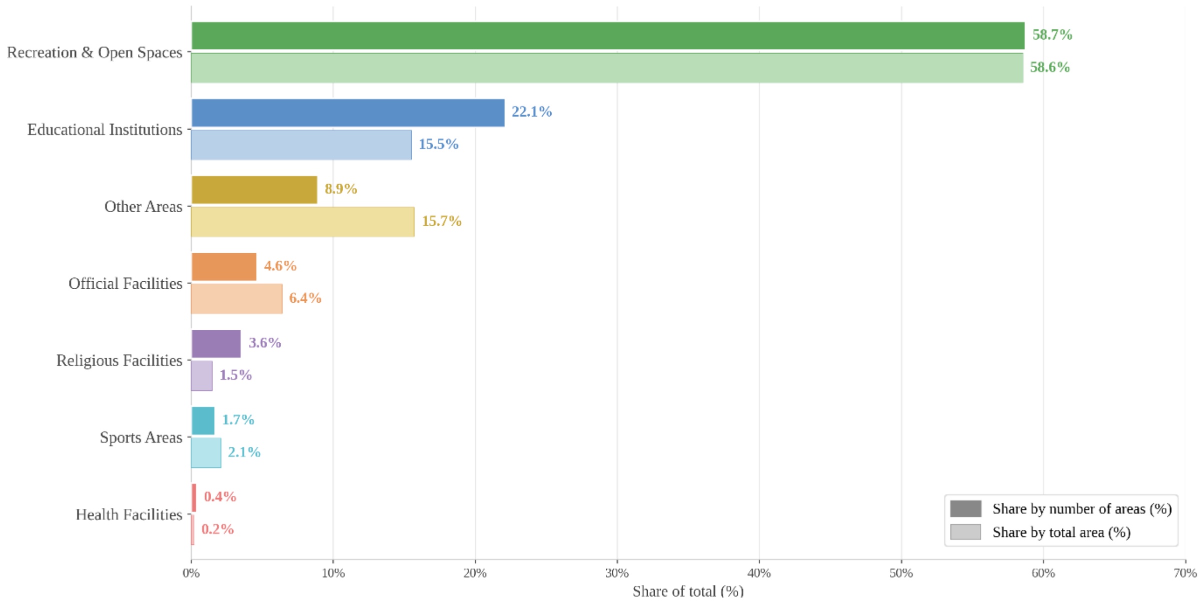


Figure 26: *Functional distribution of designated assembly areas in Istanbul by number of areas and total area. Source: Produced within the scope of this study using AFAD / IBB 2024 assembly area data*.

Certain features of the spaces designated as assembly areas draw particular attention. Notably, it was observed that the plazas in front of shopping malls have been designated as assembly areas, while the mall buildings themselves have been assigned as temporary shelter areas. To meet the gathering and temporary accommodation needs of populations whose homes became uninhabitable after the earthquake, national gardens, stadiums, major squares, open sports grounds, parks, military zones, sports facilities and shopping malls were included in this scope. In this context, it was identified that, in addition to iconic locations such as Sultanahmet Square, Taksim Square and Gezi Park, several shopping mall sites, such as the plaza of Palladium, the parking area of Cevahir Shopping Mall, the garden of Nautilus Shopping Mall and the garden of Maltepe Shopping Mall, were designated as assembly and temporary shelter areas.

The per-capita size of assembly and temporary shelter areas in disaster and emergency situations is an important criterion for evaluating post-disaster spatial adequacy. International humanitarian frameworks increasingly emphasise the importance of adequate space provision in post-disaster shelter, temporary settlement and emergency planning processes. The Sphere Project, which is widely recognised by international humanitarian organisations, was established to safeguard fundamental rights under disaster conditions and to improve the quality of humanitarian assistance (UNHCR, 2025).

In this context, the 2018 Sphere Handbook provides a relevant reference for understanding how spatial adequacy is addressed in post-disaster humanitarian planning. Sphere places particular emphasis on the relationship between available space, shelter quality, access to basic services and the dignity of affected populations. It recommends a minimum of 3.5 m^2 of covered living space per person and identifies 30-45 m^2 per person as a planning benchmark for temporary settlement areas, including household plots, circulation, communal services and infrastructure. These values highlight the broader spatial requirements that may emerge after the initial gathering phase of a disaster and underline the importance of considering assembly areas together with subsequent shelter and settlement needs (Sphere Association, 2018). .

Based on the spatial analyses conducted, the average assembly area per capita across Istanbul was calculated to be approximately 2.98 m^2. This figure provides an important indication of the spatial capacity available during the initial gathering phase of a disaster. When considered together with international humanitarian discussions on post-disaster shelter and temporary settlement needs, it also highlights the importance of evaluating assembly areas as part of a broader disaster preparedness system, rather than only as short-term meeting points. In this regard, assembly areas should be planned in connection with infrastructure capacity, transportation accessibility and the provision of basic services, so that they can respond not only to immediate gathering needs but also to essential post-disaster requirements. This underlines the need to reassess and strengthen Istanbul's urban disaster preparedness strategies.

9.2 District and neighbourhood-level analysis

In this section, an analytical study was conducted to determine the per capita assembly area for each district and to assess the adequacy of the current situation. The analysis considered the size of designated assembly areas in square metres, while population data were drawn from the 2024 district-level Address Based Population Registration System (ADNKS) statistics published by the Turkish Statistical Institute (TÜİK).

The results reveal marked differences among Istanbul's districts in terms of per capita assembly area provision. The highest values are observed in Bakırköy, Şile, Başakşehir and Çatalca, with 9.48 m^2/person, 8.11 m^2/person, 6.81 m^2/person and 6.15 m^2/person, respectively. These districts are in a relatively more advantageous position regarding post-disaster gathering capacity, reflecting a higher availability of open space per resident. This pattern can be associated with the presence of large-scale open and green areas, such as Atatürk Urban Forest in Bakırköy, as well as the lower-density urban structure and wider open-space availability in peripheral districts such as Şile and Çatalca (Figure 27).

However, the overall pattern also indicates that assembly area provision remains limited in much of the city. The Istanbul average is 2.98 m^2/person, which falls below the 3.5 m^2/person reference value shown in the figure. Several densely populated and highly urbanised districts are below this threshold, indicating insufficient open-space capacity for post-disaster gathering. The lowest values are observed in Bahçelievler, Gaziosmanpaşa, Bağcılar, Beyoğlu and Sancaktepe, all of which remain below 2 m^2/person. These districts are therefore significantly disadvantaged in terms of post-disaster gathering potential, reflecting the combined effects of high population density, compact urban form and limited available open space.

This district-level pattern is consistent with the compound vulnerability identified in Chapter 4, where several of the same districts were associated with overlapping social, physical and spatial risk factors. Overall, the findings suggest that disaster assembly area planning should prioritise districts below the 3.5 m^2/person reference value, particularly those below 2 m^2/person, through strategies that increase accessible open space and improve local emergency gathering capacity.

Although the district-level assessment reveals broad spatial inequalities in assembly area provision, district averages may mask substantial intra-district variation. In other words, a district with a relatively moderate or high average value may still contain neighbourhoods with very limited access to designated assembly areas. For this reason, the analysis was extended to the neighbourhood level in order to provide a more detailed understanding of local disparities. This finer spatial scale allows the identification of critical neighbourhoods where per-capita assembly area availability is especially low and where planning interventions should be prioritised.

Figure 28 illustrates substantial neighbourhood-level disparities in per-capita assembly area availability across Istanbul. The map shows that many neighbourhoods, particularly in densely urbanised central areas, remain below 3.5 m^2/person or have no designated assembly areas, while relatively higher values are more common in peripheral parts of the city. While many densely urbanised central neighbourhoods remain below the 3.5 m^2/person threshold, relatively higher values in some coastal and central locations can be linked to the presence of large public open spaces, including Gülhane Park in Fatih, Maçka Park in Beşiktaş and Atatürk

Urban Forest in Bakırköy. These large-scale open spaces increase the designated assembly area provision at the neighbourhood scale and partly explain the higher values observed in otherwise densely urbanised parts of the city.

In areas with the most limited assembly capacity, the ten highlighted neighbourhoods indicate the most critical cases of insufficient per-capita assembly area provision. These neighbourhoods record values below 0.10 m^2/person, indicating an extremely limited level of designated gathering capacity relative to their population. The lowest values are observed in İstiklal and Necip Fazıl Kısakürek in Esenyurt, Mareşal Çakmak and Akıncılar in Güngören, Şemsipaşa in Gaziosmanpaşa, Hılamur Kuyu in Ümraniye, Nuripaşa in Zeytinburnu, Fikirtepe in Kadıköy, Ortaköy in Kağıthane and Ataköy 7-8-9-10. Kısım in Bakırköy. The concentration of several of these neighbourhoods in densely developed districts such as Esenyurt, Güngören and Gaziosmanpaşa points to localised deficiencies that may be obscured by district-level averages.

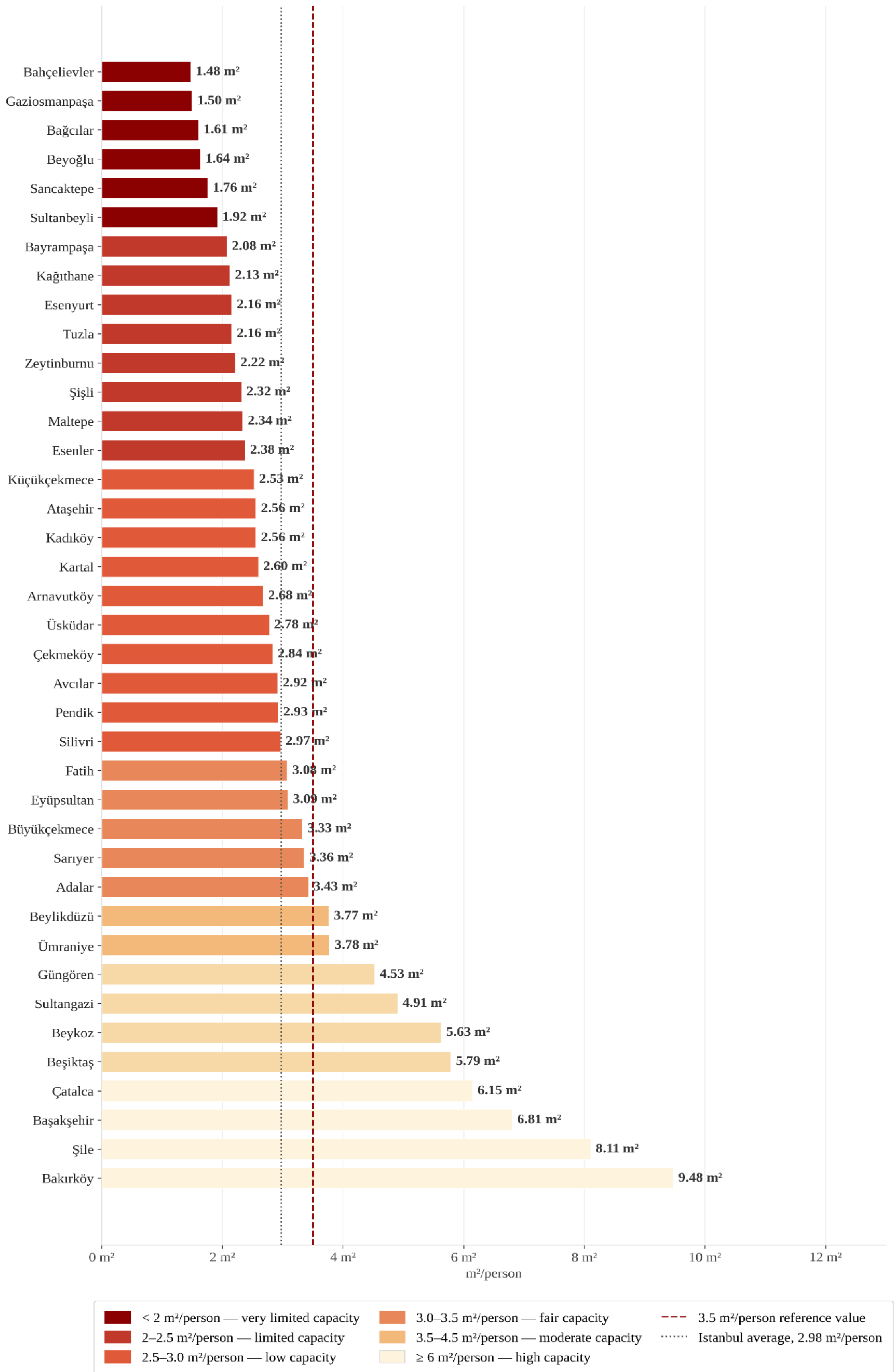
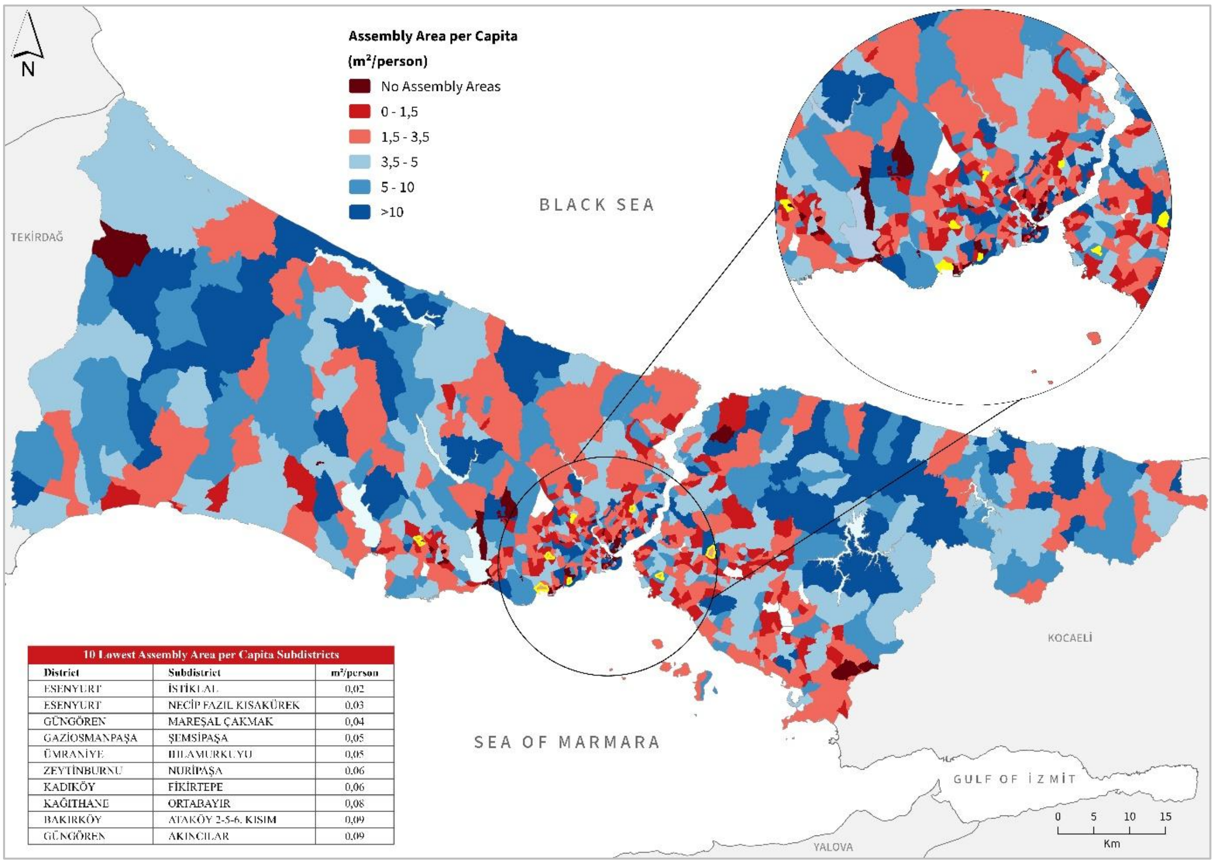


Figure 27: *Per-capita assembly area by district (m²/person). Data source: AFAD/IBB data and TÜİK 2024 ADNKS population statistics.*



10 Lowest Assembly Area per Capita Subdistricts		
District	Subdistrict	m²/person
ESENYURT	İSTİKLAL	0,02
ESENYURT	NECİP FAZIL KISAKÜREK	0,03
GÜNGÖREN	MAREŞAL ÇAKMAK	0,04
GAZİOSMANPAŞA	ŞEMSİPAŞA	0,05
ÜMRANİYE	IHLAMURKUYU	0,05
ZEYTİNBURNU	NURİPAŞA	0,06
KADIKÖY	FİKİRTEPE	0,06
KAĞITHANE	ORTABAYIR	0,08
BAKIRKÖY	ATAKÖY 2-5-6. KISIM	0,09
GÜNGÖREN	AKINCILAR	0,09

Figure 28: *Per-capita assembly areas by neighbourhood. Red tones = below 3.5 m² or zero (Karagöz and Aktas, 2026).*

Overall, the analysis shows that assembly area provision in Istanbul is unevenly distributed and remains insufficient in several densely urbanised districts and neighbourhoods. District-level results indicate that many areas fall below the 3.5 m²/person reference value, while the neighbourhood-level analysis further reveals localised shortages that may be hidden by district averages. The lowest-ranked neighbourhoods are generally located in compact urban settings where population pressure and limited open-space availability constrain post-disaster gathering capacity. These findings suggest that assembly area planning should be addressed not only through the designation of additional sites, but also through the protection, accessibility and functional improvement of existing open spaces. Future planning should prioritise neighbourhoods with very low per-capita provision and ensure that assembly areas are physically accessible, legally protected and operationally usable during an emergency.

9.3 Real-world performance on 23-24 April 2025

The social media evidence log (Annex B) documents both systematic failures and isolated positive cases in Istanbul's assembly area system on the night of 23 April. The evidence base covers 70 entries (MAR-001 to MAR-073) collected across the period 23 April–30 May 2025; entries directly relevant to assembly area performance are cited below.

The failures were both operational and structural. In Taksim, Gezi Parkı – a formally designated assembly area – was blocked by police on the night of 23 April, with officers documented on video patrolling the perimeter to prevent entry (MAR-013). In Bağcılar, the absence of any accessible assembly area in the district meant that residents spent the night on the highway (MAR-015). In Sancaktepe, the Halk Eğitim Merkezi designated assembly area had its garden gate locked at the time residents needed it (MAR-043, documented by BBC Türkçe). In Şişli, an active construction site had encroached upon and occupied part of the designated assembly area, rendering it partially unusable (MAR-035). In Sultangazi

(Sultançiftliği), video evidence showed not merely an inadequate assembly area but the complete absence of any functional one (MAR-011). In Nişantaşı, the former Marmara Üniversitesi campus – previously a large open assembly area – had been redeveloped into a luxury residential complex; a local neighbourhood association had campaigned against the conversion and lost (MAR-010).

These six documented failures share a common structure: they are not the result of unexpected conditions on 23 April. Locked gates, construction encroachment and prior commercial conversion are pre-existing, knowable conditions that an operational audit would have identified. The failures are therefore not failures of the earthquake; they are failures of the governance and maintenance regime that allowed the assembly area system to reach 23 April in this condition.

Alongside the failures, three positive cases were documented. Kadıköy Gazhane was spontaneously converted to a gathering point by local residents and the district municipality, with the mayor describing it as 'our collective garden' (MAR-004). Beylikdüzü Yaşam Vadisi functioned well as a large, accessible open space with adequate per-capita provision (MAR-016). Kuleli Parkı in Bahçelievler provided overnight shelter for displaced families, including households who had been displaced from Malatya by the 2023 earthquake and were already living in Istanbul without permanent housing (MAR-036). The common feature of the positive cases is that they involve either purpose-designed open spaces with adequate area and management infrastructure, or spontaneous community-led appropriation of accessible public space – not the designated but dysfunctional areas that the official system nominally provides.

The overall picture from 23–24 April is of a system that passed by numerical count and failed by operational reality. Approximately 100,000 people needed the assembly area system on a night with no structural collapse, no fires, functioning utilities and mild weather – the most favourable possible conditions. The documented failures occurred under those conditions. The implications for a Mw 7+ event, in which the displaced population may be two orders of magnitude larger and conditions far more adverse, require no elaboration.

9.4 Conclusions

The 23 April 2025 event was the most significant real-world stress test of Istanbul's assembly area system to date. The system passed by sheer numerical count (5,570 areas) but failed by spatial distribution, per-capita adequacy (2.98 m² vs. 3.5 m² Sphere minimum), and operational functionality (locked gates, construction-occupied plots, police blockade of formally designated areas). The 419 assembly areas opened to development since 1999 represent a self-inflicted reduction in the city's preparedness capacity. The 23 April rehearsal, at Mw 6.2, exposed these gaps in a context where approximately 100,000 people needed the system without meaningful structural damage having occurred. At Mw 7+, with actual structural collapse and an order of magnitude more displaced residents, these gaps will not be manageable.

10. Conclusions and Forward Look

Chapter summary in plain terms

This chapter draws together the findings of the report and assesses what the 2025 earthquake reveals about Istanbul's readiness for the major anticipated event. The 2025 event is best understood not as a test that the city passed but as a warning about a test that has not yet arrived: the rupture released approximately 8% of the accumulated slip deficit on the Kumburgaz segment, leaving 3.4 m of slip deficit locked on a fault segment beneath a metropolitan area of sixteen million people, with probabilistic estimates of a Mw≥7 rupture on the Princes' Islands segment ranging from 35% to 70% in the coming decades. Scenario loss studies estimate 14,000 to 87,000 fatalities under a Mw 7.5 event – a test the 2025 earthquake, with ground motions well below DD-2 design levels, did not constitute.

The engineering infrastructure that has received sustained investment since 1999 performed well: early warning, gas shut-off and base-isolated hospitals all functioned as designed. The building stock was not substantively tested. The urban transformation programme has been expanded following the event, but at its current delivery rate the 600,000+ high-risk units in Istanbul will not be substantially reduced before the next moderate event. The societal and institutional systems – assembly areas, insurance, housing market, telecommunications, official communication – were each exposed as deficient under conditions far less demanding than those the major event will produce. The 100,000 people outdoors overnight, the tripling of bus fares and the 100% rent surge in stable-ground districts are not anomalous panic responses: they are the rational behaviour of a population that has internalised decades of seismic risk awareness and whose institutional protections failed at moderate scale.

The compound spatial concentration of physical vulnerability, social disadvantage and institutional inadequacy in the same European-side districts is the central preparedness challenge. The chapter identifies five specific policy interventions required: legal protection and operational audit of the assembly area register; revision of DASK deductible structures and coverage ceilings; expansion and reorientation of the urban transformation programme toward the highest-risk districts, with retrofit subsidies equivalent to demolition subsidies; mandatory telecommunications resilience standards; and building inspection enforcement capable of identifying construction defects. None requires new engineering knowledge. All require political decisions that have been postponed through successive moderate earthquakes. This report provides a timestamped record of what was known, what was visible and what remained unaddressed as of May 2026 – a record that will be relevant regardless of whether reform precedes or follows the major event.

10.1 The event in its seismological context

The Mw 6.2 Western Marmara Sea earthquake of 23 April 2025 was the largest rupture on the Main Marmara Fault in more than sixty years. It struck the Kumburgaz segment at shallow depth, lasted approximately 13 seconds, generated a 212-station (within 200 km of the source) strong-motion dataset of exceptional density, and produced one fatality, 359 injuries across the Marmara region, and 4,295 buildings classified as slightly damaged (*az hasarlı*) in Istanbul (Kurum, 2025a). By the conventional metrics of post-earthquake assessment, it was a moderate event.

The seismological significance of the event lies not in what it produced but in what it did not. The rupture released approximately 0.3 m of the estimated 3.7 m of slip deficit accumulated on the Kumburgaz segment since the last major rupture in 1766 – equivalent to approximately

8% of the accumulated strain (İTÜ MATAM, 2025). The remaining slip deficit of approximately 3.4 m remains locked on a fault segment beneath a metropolitan area of sixteen million people (Bohnhoff et al., 2013). Martínez-Garzón et al. (2025) place the 2025 event within a fifteen-year sequence of eastward-migrating moderate ruptures converging on the locked Princes' Islands segment south of Istanbul's historic peninsula – the source of the anticipated Mw 7+ event. The aftershock sequence of the 2025 earthquake, which migrated eastward toward this locked segment within 24 hours of the mainshock, is consistent with this interpretation. Probabilistic estimates of the likelihood of a Mw ≥7 rupture on the Princes' Islands segment (Bohnhoff et al., 2013) range from 35% to 70% over the coming decades (Parsons et al., 2000; Murru et al., 2016); the 2025 event has incrementally increased rather than relieved that probability.

The 2025 earthquake is therefore best understood not as a seismic event that tested Istanbul's resilience, but as a warning about an event that has not yet occurred and that will be substantially more damaging when it does.

10.2 What the 2025 event revealed about engineering preparedness

The engineering systems that have received sustained investment since 1999 performed largely as intended. The Istanbul Earthquake Rapid Response and Early Warning System (IERREWS) and the IGDAŞ natural gas automatic shut-off network (IGRAS) triggered correctly. Eight base-isolated hospitals remained fully operational. The AFAD-TADAS and KOERI strong-motion networks delivered one of the densest urban ground motion records in the world. These outcomes reflect genuine progress and should be recognized.

The building stock, by contrast, was not substantively tested. Recorded ground motions remained well below DD-2 design levels – the standard design earthquake with a 10% probability of exceedance in 50 years – at all stations, with the ratio of recorded to design PGA varying considerably across the network depending on epicentral distance and local site conditions. Aydoğdu and İlki (2026) demonstrate that the light damage observed is a function of the short 13-second ground motion duration as much as it is of structural adequacy: the same buildings, subjected to a longer-duration record of comparable PGA, would not survive. The ESDOF analyses presented in Chapter 5 confirm that inelastic demand was already reached in vulnerable typologies at Küçükçekmece, Bakırköy, Avcılar and Silivri under this sub-design loading – districts that correspond precisely to those identified as highest-risk in every scenario loss study since 2002.

The building stock assessment presented here (Chapter 3) contextualises this finding. As of 2019, approximately 70% of Istanbul's buildings predate the post-1999 regulatory transition related to the update of the seismic design code. The districts generating the highest damage report concentrations in 2025 – Bahçelievler, Esenler, Bağcılar, Zeytinburnu, Esenyurt – combine pre-1975 and pre-1999 RC frame stock with soft alluvial ground conditions and are the same districts flagged as highest-risk in the IMM/JICA (2002) and IMM/KOERI (2019) scenario studies. The estimated scenario fatalities for a Mw 7.5 event range from 14,000 to 87,000 depending on methodology and time of day. The 2025 event, with recorded ground motions well below DD-2 design levels, produced no structural fatalities. This is not evidence of resilience. It is evidence of how far the anticipated major event exceeds anything the building stock has been tested against.

The urban transformation programme, *Yarısı Bizden*, has been extended and promoted in the aftermath of the event. Minister Kurum subsequently announced that of 452,000 homes and businesses assessed, 61,000 had been classified as slightly damaged and approximately 250,000 residents in those units would be eligible for the *Yarısı Bizden* programme (MAR-065). Minister Kurum's statement that 61,000 slightly damaged units are eligible for the programme is a measure of the scale of need: at the current rate of programme delivery, the residual risk represented by 600,000+ high-risk units will not be substantially reduced before the next moderate event, let alone before the major rupture.

10.3 What the 2025 event revealed about societal and institutional preparedness

The most analytically significant findings of this report are not in the engineering chapters. They are in the chapters that document what happened to Istanbul's population and institutions when a moderate earthquake – producing no structural fatalities, no collapse of inhabited buildings, no failure of major lifelines – caused 100,000 people to spend at least one night outdoors.

The Fear of Earthquake Scale data collected by EMSC in near-real time in the hours following the mainshock (Section §7.4.2) provide the first quantitative psychometric evidence for a proposition that this report's behavioural evidence has made impossible to ignore: Istanbul's population is not responding to the 2025 event in isolation. It is activating a chronic, elevated fear baseline that has been accumulating for decades. A mean FES score of 22.60/35 with 42% of respondents in the high-fear range, generated by an earthquake that caused one fatality, is not a disproportionate panic response. It is consistent with a population that has internalised decades of seismic risk awareness. The 100,000 people outdoors, the tripling of bus fares, the 100% surge in rents in stable-ground districts within hours of the mainshock, the sustained outmigration of 950,000 people from Istanbul in 2023 and 2024 – these are not anomalies. They are the rational behaviour of a population that knows, at some level, that the larger event is coming and that its institutional protections may not hold.

The institutional failures exposed by the 2025 event are well-documented in Chapters 6, 7 and 8 of this report. Three warrant particular emphasis in these conclusions.

The assembly area system was tested at the most favourable possible scale – no structural collapse, mild weather, functioning utilities, a public holiday that had already placed people outdoors – and it failed operationally. Locked gates, construction sites inside designated areas, police blockade of a formally designated space, and districts with no functional capacity were all documented in real time from the social media evidence log (Annex A). The average per-capita assembly area provision across Istanbul of 2.98 m^2 falls below the Sphere Project minimum of 3.5 m^2, and 419 of 496 post-1999 designated areas have been converted to commercial development. These are not new findings. They have been documented in earlier EEFIT Türkiye assessments and in the academic literature. They remain unaddressed.

The DASK compulsory earthquake insurance system was tested against the damage category – light cracking, plaster failure, tile loss – that constitutes the vast majority of damage in a moderate urban earthquake. It paid out as little as 6,400 TL for multi-room damage, near-zero after deductibles in multiple documented cases, and in one instance declared column damage 'not from earthquake but from aging. The deductible and coverage ceiling structures that produce these outcomes are well understood and have been documented as inadequate after the Elazığ, İzmir and Düzce earthquakes. They remain unaddressed.

The housing market sorted by perceived seismic safety within hours of the mainshock, with prices rising over 100% in stable-ground districts. This is not price gouging in the conventional sense: it is a functioning market responding to information that the population has internalised over decades of seismic risk awareness. The consequence is a progressive concentration of lower-income households in the most vulnerable districts, with the least assembly area provision and the oldest building stock. Risk and vulnerability are not randomly distributed across Istanbul. They are being concentrated in the same spatial pattern, by the same market dynamics, that the scenario loss studies have been documenting since 2002.

10.4 The compound spatial vulnerability

One of the central findings that emerges from reading the technical and societal chapters of this report together is that the physical, social and institutional dimensions of Istanbul's earthquake risk are not independent. They are co-located and mutually reinforcing.

The districts generating the highest building damage report concentrations in 2025 (Bahçelievler, Esenler, Bağcılar, Zeytinburnu, Avcılar, Esenyurt) are the same districts with the lowest per-capita assembly area provision, the highest proportions of pre-1999 building stock on soft alluvial ground, the highest rates of lower-income household concentration following seismic-risk-driven outmigration by higher-income residents, and the greatest historical difficulty with urban transformation programme uptake. These are also the districts where DASK payout inadequacy will matter most in the major event, because the households with the fewest resources to absorb uninsured repair costs are concentrated here.

This co-location is not accidental. It is the product of sixty years of urban development dynamics in which rapid informal urbanisation, successive regulatory frameworks that were not enforced, construction amnesties that retroactively legitimised non-compliant buildings, and housing market dynamics driven by seismic risk awareness have all operated in the same direction: concentrating physical vulnerability and institutional inadequacy in the same places. The 2025 earthquake did not create this pattern. It confirmed it, under recorded ground motions that remained well below code DD-2 design levels.

10.5 The preparedness gap and what could close it

The failures documented in this report are not technically intractable. They do not require new engineering knowledge, new scientific understanding, or new institutional architecture. They require political decisions that have been postponed through successive moderate events.

The assembly area register requires legal protection to prevent further conversion to commercial development, and an operational audit to identify which of the 5,570 currently designated areas are actually accessible and functional. The DASK system requires revision of its deductible structure and coverage ceilings to provide meaningful protection for the light-to-moderate damage category that moderate events produce. The urban transformation programme requires acceleration at a scale proportionate to the 600,000+ high-risk unit figure, with particular prioritisation of the highest-risk districts. The telecommunications infrastructure requires mandatory post-earthquake resilience standards that have not been established in 26 years since the 1999 İzmit earthquake. The building inspection regime requires enforcement mechanisms capable of identifying the kinds of construction defects – mussel shells in concrete columns, inadequate stirrup hooks, informal structural modifications – that the 2025 event made visible in Küçükçekmece.

None of these interventions is contingent on new knowledge. All of them are contingent on political will and institutional capacity. EEFIT is not positioned to determine whether that will exists, or when it will be applied. What EEFIT can do – and what this report attempts to do – is provide a specific, documented and timestamped account of what was known, what was visible, and what remained unaddressed as of May 2026. That record will be relevant regardless of whether reform precedes or follows the major event.

10.6 Priorities for future research and monitoring

Several analytical gaps identified by this report warrant continued investigation.

The 212-station ground motion dataset assembled for Chapter 2 is one of the densest urban strong-motion records produced by any moderate earthquake. A full regional analysis extending beyond the Istanbul stations to include Bursa, Kocaeli, Sakarya and Tekirdağ – held back from this report to preserve the basis for a dedicated publication – would substantially advance understanding of attenuation patterns and basin amplification along the Main Marmara Fault. The finding that median PGA estimations from KAAH15 exhibit consistent underestimation for this source region warrants further evaluation of the regional hazard basis for the Marmara region.

The ESDOF damage prediction in Chapter 5 uses models calibrated for the Erzincan building stock. An Istanbul-specific equivalent SDOF model pool, calibrated to the city's dominant typologies – mid-rise RC frame, tunnel-form mass housing, pre-1975 flat-slab construction – would substantially improve the reliability of damage predictions for the anticipated major event and provide a basis for tracking change in the vulnerable stock over time.

The Fear of Earthquake Scale data collected in near-real time by EMSC following the 2025 event represent a methodological innovation in post-earthquake societal research. Full subscale analysis, matching with felt intensity reports, and contextualisation within Istanbul's documented outmigration and housing market dynamics would contribute to understanding the relationship between chronic seismic fear and behavioural response in urban populations living in proximity to unruptured fault segments. This is directly relevant to emergency planning assumptions about population behaviour in the major event.

The assembly area analysis presented in Chapter 9 establishes a baseline against which future changes to the designated area register should be monitored. Whether the areas added immediately after the 2025 earthquake are retained, protected and made operationally functional, or whether the post-event designation surge is followed by the same pattern of gradual commercial conversion that eroded the post-1999 register, is a directly observable outcome that should be tracked.

The building damage data produced by ministerial inspection teams following the 2025 event – 25,017 buildings assessed, 2,928 classified as damaged – have not yet been released in disaggregated form by structural typology, construction period or district. When released, systematic comparison of the 2025 damage geography against the IMM/KOERI (2019) scenario loss predictions would provide a rare empirical validation of a probabilistic urban risk model under real moderate loading. EEFIT recommends that these data be made publicly available in disaggregated form at the earliest opportunity.

Finally, the three institutional failures documented in Chapters 7 and 8 – DASK coverage inadequacy, assembly area erosion, and construction amnesty accumulation – are each directly observable and measurable over time. Whether regulatory reform follows the 2025 event or whether the political cycle returns to complacency until the next moderate earthquake is a question that will be visible in specific, trackable outcomes: DASK tariff revisions, assembly area legal protection, urban transformation programme delivery rates, and building inspection enforcement records. These are the leading indicators of whether Istanbul's preparedness for the major anticipated event is improving or deteriorating. Monitoring them is the most direct contribution that continued research engagement with this region can make.

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Annex: Social Media Evidence Log

April-May 2025

Total entries: 70 (MAR-001 to MAR-074).

Note: MAR-059, MAR-062, MAR-069 and MAR-071 have been removed as duplicates; reference numbers are not reused.

This log documents social media posts collected systematically in the days following the 23 April 2025 Mw 6.2 Western Marmara Sea earthquake. Entries were identified through keyword searches on X (formerly Twitter) and Instagram. Each entry carries a unique reference identifier (MAR-xxx) cited in the main report. All URLs were accessible at time of logging.

Category colour key:

Behaviour / Assembly Areas	Building Damage	Governance / Communication	Economics / Insurance

ID	Location	Date	Platform	Author type	Media	Summary of evidence
MAR-001	Beyoğlu – Taksim	23 Apr	X	*official*	photo	AKP Beyoğlu party official visiting citizens in street after earthquake.
MAR-002	Fatih – Tahtakale	23 Apr	X	*news*	video	Video of crowds pouring into streets in Tahtakale immediately after shaking.
MAR-003	Fatih	23 Apr	X	*news*	text	Breaking news: 3-storey derelict building collapsed in Fatih after 6.2 earthquake.
MAR-004	Kadıköy – Gazhane	23 Apr	X	*official*	video	District mayor: residents spontaneously converted Gazhane to assembly point – 'our collective garden'.
MAR-005	Kuzey Marmara Otoyolu	23 Apr	X	*news*	video	Traffic jam on Kuzey Marmara Motorway as residents attempt to leave Istanbul.
MAR-006	Istanbul (general)	29 Apr	X	*news*	photo	Minister Kurum confirms 25,017 buildings inspected; 2,928 confirmed damaged as of 29 April.

MAR-007	Istanbul (general)	23 Apr	X	*private individual*	text	'Took 30 min by car to reach park 2 km away. Phones not working. WhatsApp not working. 2025 and we experienced this disgrace.'
MAR-008	Istanbul (general)	23 Apr	X	*private individual*	text	Went to designated park within 30 min – 'like Judgement Day'. Couldn't stay 1 hour. Another felt aftershock on return.
MAR-009	Istanbul (general)	23 Apr	X	*private individual*	text	'Not even a safe area to flee to – park surrounded by buildings, no room to move. We just wait to die quietly.'
MAR-010	Şişli – Nişantaşı	24 Apr	X	*private individual*	text	Former Marmara Üniversitesi Nişantaşı campus converted to luxury residential complex. Neighbourhood association had campaigned to retain it as assembly area.
MAR-011	Sultangazi – Sultançiftliği	23 Apr	X	*private individual*	video	'The earthquake showed there is no assembly area in Istanbul.' Video of Sultançiftliği showing no functional area.
MAR-012	Zeytinburnu	24 Apr	X	*private individual*	photo	TOKİ housing estate assembly area is a pavement between roads. Photo.
MAR-013	Taksim	23 Apr	X	*private individual*	video	Gezi Parkı – formally designated assembly area – blocked by police on night of 23 April. Patrols documented on video.
MAR-014	Şişli – Teşvikiye	25 Apr	X	*private individual*	video	Teşvikiye designated assembly area transferred to private housing construction on most valuable land in Istanbul.
MAR-015	Bağcılar	25 Apr	X	*private individual*	photo	People in Bağcılar spent the night on the highway because there was no assembly area in the district.
MAR-016	Beylikdüzü – Yaşam Vadisi	23 Apr	X	*journalist*	photo	Beylikdüzü Yaşam Vadisi functioning well as assembly area. Credited to IBB management.
MAR-017	Etiler	24 Apr	X	*private individual*	photo	Former Polis Koleji site – designated assembly area – now has rent towers under construction. Photo.
MAR-018	Istanbul (general)	24 Apr	X	*professional body*	photo	Mekanda Adalet Derneği: 'We were confronted once again with how far Istanbul's assembly areas are from meeting the most urgent needs.'
MAR-019	Esenyurt	24 Apr	X	*news*	video	Esenyurt resident climbs to rooftop while others evacuate to street after earthquake.

MAR-020	Esenler	24 Apr	X	*news*	video	Group of residents in Esenler making *gözleme* on the street, planning to sleep outdoors.
MAR-021	Güngören	23 Apr	X	*news*	video	Video of park in Güngören packed with residents sheltering after earthquake.
MAR-022	Istanbul (general)	24 Apr	X	*news*	video	President Erdoğan visits Istanbul during earthquake night, continues touring.
MAR-023	Nişantaşı	24 Apr	X	*news*	video	Video: women evacuating buildings in Nişantaşı, trying to stay in safe outdoor areas.
MAR-024	Istanbul (general)	23 Apr	X	*news*	text	Istanbul Valiliği: 'School courtyards, sports halls and mosques opened for citizens who do not wish to remain in their homes.'
MAR-025	Istanbul (general)	23 Apr	X	*unknown*	photo	GSM network saturation documented. Traffic +71%, aircraft cancellations +350%. 'Operators collapsed.'
MAR-026	Beylikdüzü	23 Apr	X	*official*	video	MP visiting citizens gathered in assembly areas along the road in Beylikdüzü.
MAR-027	Kadıköy – Yoğurtçu Parkı	24 Apr	X	*news*	video	Euronews Türkçe: Kadıköy residents sheltering overnight in tents at Yoğurtçu Parkı.
MAR-028	Kadıköy – Fikirtepe	24 Apr	X	*private individual*	video	Video of Fikirtepe redevelopment: 'What will happen here in a major earthquake? Then we'll say it was God's will.'
MAR-029	Fatih	23 Apr	X	*news*	video	Patient being carried out of building on stretcher during earthquake in Fatih.
MAR-030	Küçükçekmece – İnönü Mah.	28 Apr	X	*news*	multi-photo	Sputnik TR: '6.2 earthquake burst building columns – mussel shells (midye kabukları) found inside concrete.' Multiple photos of fractured columns.
MAR-031	Fatih	23 Apr	X	*private individual*	video	'In a 7.5 earthquake, even if everyone is in the street, minimum 200–300k will die. Nowhere to run.'
MAR-032	Kağıthane	23 Apr	X	*private individual*	text	'In Kağıthane, shook a lot, people came out of buildings.'

MAR-033	Istanbul (general)	23 Apr	X	*private individual*	text	'Came outside but surrounded by 7–8 storey buildings. Nowhere to run, no assembly area. If you escape the building, neighbouring ones will crush you.'
MAR-034	Kadıköy – Hasanpaşa	23 Apr	X	*private individual*	text	'The building we said would collapse at 5 survived. No buildings collapsed in Kadıköy Hasanpaşa.' (Positive report.)
MAR-035	Şişli	23 Apr	X	*private individual*	video	'Came out but not a single square to feel safe – ran between buildings.' Active construction site inside designated assembly area (Şişli).
MAR-036	Bahçelievler	23 Apr	X	*news*	video	TvCumhuriyet: Family displaced from Malatya in 2023 earthquake – Istanbul home damaged in 2025 event. Living in tent in Kuleli Parkı (Bahçelievler).
MAR-037	Küçükçekmece	29 Apr	X	*news*	photo	'Mussel shells seen in columns of damaged building in Küçükçekmece.' Different angle from MAR-030.
MAR-038	Bağcılar	29 Apr	X	*news*	photo	Halk TV: 'New hospital sustained damage in 6.2 earthquake.' [Bağcılar hospital]
MAR-039	Istanbul (general)	23 Apr	X	*news*	text	Minister Kurum at 19:41 on 23 April: '378 structural damage reports received to 112 so far.'
MAR-040	Fatih – Çapa Tıp Fak.	28 Apr	X	*private individual*	photo	Photo with hashtag #ÇapaMezarOlmasın (Don't let Çapa become a grave) – concern about Cerrahpaşa / Çapa hospital campus.
MAR-041	Istanbul (general)	25 Apr	X	*news*	video	Report on aftershocks continuing to be felt in districts over following days; residents remaining cautious.
MAR-042	Istanbul (general)	23 Apr	X	*news*	video	Broadcaster: 'Couldn't reach mother or girlfriend by phone. In a big earthquake what will people do? How will they communicate?' GSM operator criticism.
MAR-043	Sancaktepe	23 Apr	Instagram	*news*	video	BBC Türkçe: Residents ran to assembly areas but many were inaccessible or overcrowded. Halk Eğitim Merkezi garden gate locked. Multiple district footage.
MAR-044	Pendik	23 Apr	Instagram	*news*	video	Panic in Pendik – residents flooding streets after shaking.
MAR-045	Esenyurt	23 Apr	Instagram	*official*	photo	Esenyurt district official visiting parks: residents frightened, requesting social facilities opened and mobile units deployed.

MAR-046	Istanbul (general)	23 Apr	Instagram	*private individual*	video	'Earthquake in Istanbul continues! Everyone rushing to parks to spend the night.'
MAR-047	Başakşehir	23 Apr	Instagram	*news*	video	Consecutive earthquakes felt and documented in Başakşehir.
MAR-048	Esenyurt	23 Apr	Instagram	*private individual*	video	'Istanbul 2025 – 23 April National Sovereignty Day. This is how we celebrated it.' Crowds outdoors in Esenyurt.
MAR-049	Bahçelievler – Şirinevler	23 Apr	Instagram	*news*	video	Panic footage in Şirinevler, Bahçelievler during earthquake shaking.
MAR-050	Fatih – Çarşamba	23 Apr	Instagram	*private individual*	video	Live footage from Fatih Çarşamba neighbourhood during earthquake.
MAR-051	Esenler	23 Apr	Instagram	*news*	photo	Cracks in occupied 5-storey building in Esenler following Mw 6.2 and Mw 5.9 events. Photo.
MAR-052	Istanbul (general)	23 Apr	Instagram	*private individual*	video	General earthquake footage tagged #deprem #Istanbuldeprem #sondakikadeprem.
MAR-053	Fatih	23 Apr	Instagram	*unknown*	video	Video of 3-storey derelict building collapse in Fatih after 6.2 earthquake.
MAR-054	Istanbul (general)	30 Apr	X	*private individual*	text	Damage statistics: no collapse, no heavy/moderate damage; 9% slight damage. Rupture threshold M6.4. 'Geçmiş olsun Istanbul.' (@ovgunaercan)
MAR-055	Kadıköy	24 Apr	X	*institutional*	text+photo	MEB official and Kadıköy district education director visited school to assess damage and accommodation status following 23 April earthquake. (@KGMTAL)
MAR-056	Istanbul (general)	28 Apr	X	*news media*	text+photo	Istanbul Governor Davut Gül stated no damage occurred in any Istanbul schools after the 23 April earthquake – contradicted within days by evacuation of four schools. (@spotmalumat)
MAR-057	Istanbul (general)	14 May	X	*private individual*	text+photo	Building vibrates when cars pass; sea shells visible in fractured column. Applied for damage assessment – DASK SMS response: 'no earthquake-related damage.' Documents both construction defect and insurance system failure. (@ucretsizwc)
MAR-058	Kocaeli	9 May	X	*private individual*	text+video	Kocaeli Güzel Sanatlar Fakültesi: 'We are living face to face with death. Our heavily damaged building was closed by the Rector after the last earthquake.' (@VFjola)

MAR-059	Şahintepe	2 May	X	*news media*	text+video	Damaged apartment interior documented in Şahintepe neighbourhood following 23 April earthquake. (@sahintepe)
MAR-060	Istanbul (general)	28 Apr	X	*news media*	text	Rental prices surged following earthquake: 0-4 year old rental properties up 66.74% year-on-year; new builds averaging 31,441 TL/month. Residents relocating from pre-2000 buildings toward newer stock in northern Istanbul. (@NewsAkf)
MAR-061	Küçükçekmece	28 Apr	X	*news media*	text	6.2 earthquake 'burst columns' in Küçükçekmece building; basement-level association evacuated. (@yeniakit)
MAR-062	Cerrahpaşa	25 Apr	X	*news media*	text+photo	Istanbul University-Cerrahpaşa: faculties relocated following damage assessments. 'Istanbul University Earthquake Crisis: Faculties Moving!' (@batiakdeniztv)
MAR-063	Istanbul (general)	26 Apr	X	*professional body*	text	Chamber of Engineers: ministry engineers conducting damage assessments risk their lives without extra pay and without a professional statute law. Calls for recognition of technical personnel rights. (@MuhTekBayindir)
MAR-064	Istanbul (general)	28 Apr	X	*news media*	text+photo	'Worker whose home is damaged cannot be dismissed.' Report on legal rights of earthquake-affected employees following 23 April event. (@sabah)
MAR-065	Istanbul (general)	8 May	X	*news media*	text+video	Minister Kurum: 452,000 homes and businesses assessed; 354,000 undamaged, 61,000 slightly damaged. Approximately 250,000 residents in slightly damaged units eligible for Yarısı Bizden programme. (@Haberturk)
MAR-066	Fatih	16 Jun	X	*official*	text+video	Fatih mayor: residents who completed urban transformation before the earthquake report no damage and no anxiety. Promotes Kentsel Dönüşüm programme. (@MErgun_Turan)
MAR-067	Istanbul (general)	14 May	X	*private individual*	text	Resident: bathroom tiles damaged, floor-to-ceiling crack in bedroom. DASK payout: 3,000 TL. Supplementary insurer says DASK must be exhausted first – DASK limit 800,000 TL but payout derisory. (@sevda190734)
MAR-068	Güngören	30 Apr	X	*news media*	text+video	Güngören municipality conducting damage assessment and evacuation operations for damaged buildings following 23 April earthquake. (@365gazete)
MAR-069	Şahintepe	2 May	X	*news media*	text+video	Second entry documenting damaged apartment in Şahintepe neighbourhood. (@sahintepe)
MAR-070	Kocaeli	9 May	X	*private individual*	text	Follow-up post: heavily damaged Kocaeli arts faculty building – if it collapses during earthquake it would block the exit of the adjacent undamaged building. 'We were lucky not to be there on 23 April.' (@VFjola)

MAR-071	Istanbul (general)	24 Apr	X	*professional body*	text+photo	Mekanda Adalet Derneği: earthquake caused mass panic; people gathered in parks but Istanbul's assembly areas are 'far from meeting even the most urgent needs.' (@mekandaadalet)
MAR-072	Istanbul (general)	30 May	X	*private individual*	text+photo	DASK victim: adjuster declared damage 'not from earthquake but from aging' – refused to pay. 'There is a policy, there is damage, but no money! What is the point of insurance in this country?' (@gorkemolmez)
MAR-073	Istanbul (general)	10 May	X	*private individual*	text	Resident: '23 April felt like the 1999 earthquake but shorter. My building was renovated in 2015 – we experienced what felt like the same intensity.' Perception of shaking relative to 1999. (@sznakhan)
MAR-074	Küçükçekmece	29	Youtube	*news media*	video	News report on an evacuated residential building in Küçükçekmece. The area is described as built on reclaimed land between the sea and Küçükçekmece Lake, with risky ground conditions. The building was reported by occupants of an adjacent building who observed pounding between the two structures during the earthquake. A total of 11 buildings were evacuated in Küçükçekmece; residents permitted re-entry only with special permit for essential belongings. Concrete from the building crumbles easily by hand and marine shell fragments are visible in the aggregate, consistent with the use of unwashed marine-sourced sand. Report also identifies Avcılar, Büyükçekmece, Esenyurt and Zeytinburnu as other high-risk districts per IMM assessments. (NTV)

Source URLs

MAR-001 https://x.com/AKBeyoglu/status/1915159641199202712
MAR-002 https://x.com/HaberReport/status/1914995260167524753
MAR-003 https://x.com/HaberReport/status/1914999725926846506
MAR-004 https://x.com/mhrpolat/status/1915040739404157226
MAR-005 https://x.com/HaberReport/status/1915100727568933141
MAR-006 https://x.com/sputnik_TR/status/1917226616813396298
MAR-007 https://x.com/AlacaGunler/status/1915059993256120566
MAR-008 https://x.com/cigdemcavusoglu/status/1915072906813493699
MAR-009 https://x.com/kubraozkan777/status/1915037882072318252
MAR-010 https://x.com/dovmelim71/status/1915175925454365154
MAR-011 https://x.com/sinanar08557376/status/1915010937917935657
MAR-012 https://x.com/OlcayUnalSert/status/1915186727574008023

MAR-013 https://x.com/Kerimbutunn/status/1915117163930697879
MAR-014 https://x.com/HIABDIK/status/1915736786971644147
MAR-015 https://x.com/h_algun/status/1915778765877137882
MAR-016 https://x.com/arzuguvennet/status/1915066483262074933
MAR-017 https://x.com/ulu_manitu/status/1915464732569477472
MAR-018 https://x.com/mekandaadalet/status/1915367191823687935
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MAR-020 https://x.com/gazetory/status/1915168443315143076
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MAR-025 https://x.com/turuksoz/status/1915001369859072186
MAR-026 https://x.com/ozturkyilmazYP/status/1915030029425160202
MAR-027 https://x.com/euronews_tr/status/1915458986897281056
MAR-028 https://x.com/MehmetTanselY/status/1915340411544969472
MAR-029 https://x.com/HaberReport/status/1915008322039673216
MAR-030 https://x.com/sputnik_TR/status/1916885118607856098
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MAR-043 https://www.instagram.com/p/DIy4opJvuC7/
MAR-044 https://www.instagram.com/p/DIyoxI3IsY1/

MAR-045 https://www.instagram.com/p/DIy7e2RoJ-o/
MAR-046 https://www.instagram.com/p/DIylJr8oON7/
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MAR-067 https://x.com/sevda190734/status/1922498165548220569
MAR-068 https://x.com/365gazete/status/1917616843457474719
MAR-070 https://x.com/VFjola/status/1920913395223535975
MAR-072 https://x.com/gorkemolmez/status/1928524341366366653
MAR-073 https://x.com/Sznakhan/status/1921304048415768980
MAR-073 https://www.youtube.com/watch?v=kf8mjo5j18o