# Supplementary Table S1:
# Complete Taxonomy Crosswalk for Multi-Source Integration

## Overview

This supplementary table provides the complete crosswalk mapping between the unified two-axis taxonomy (Domain × Scale) and classification schemes used in five heterogeneous data sources: Survey, Social Media, EM-DAT, Copernicus EMS, and Literature.

## Purpose

These mappings enable consistent aggregation and thematic comparison across fundamentally different data structures. Researchers can use this crosswalk to:

- Code new events from any source into the unified taxonomy
- Aggregate domain-level statistics across sources
- Check thematic cross-source consistency
- Adapt the framework to additional data sources

## Crosswalk Principles

1. **Many-to-one mapping**: Multiple source-specific categories may map to a single taxonomy domain (e.g., both "traffic jam" and "road closure" map to Transport).
2. **Hierarchical inheritance**: Scale assignments depend on event magnitude; the same disaster type (e.g., flood) can appear at multiple scales.
3. **Context-dependent assignment**: Where source categories are ambiguous, supplementary metadata (duration, spatial extent, affected population) guide scale assignment.
4. **Scale precedence rule**: Where spatial extent, duration, and systemic consequence point in different directions, systemic consequence takes precedence over spatial extent, and spatial extent over duration. For example, a short-lived metro closure that cascades into district-wide congestion is coded Mid-scale despite its limited duration and point-like origin (see also Example 2, where a city-wide systemic consequence determines Large scale).
5. **Trigger and impact coding**: Domains are mutually exclusive within each coding field. Events that cascade across domains receive a trigger-domain code and a separate impact-domain code (as in Examples 1 to 3). Aggregate domain counts are computed on the trigger (primary) domain only, so that no event contributes to more than one domain total; impact-domain tallies may be produced separately where a cascade perspective is required.

## Table S1.1: Survey Question Mapping

Table 1: Survey disruption categories mapped to unified taxonomy

| Survey Category | Taxonomy Domain | Typical Scale | Notes |
|---|---|---|---|
| **Transport-Related Disruptions** | | | |
| Public transport delays or cancellations | Transport | Daily/Mid | Scale depends on duration: ¡2hr = Daily; 2-24hr = Mid |
| Strikes (transport services) | Transport | Mid/Large | Single-line = Mid; network-wide = Large |
| Traffic signal outages or malfunctions | Transport | Daily | Unless cascading to network-level congestion |
| Heavy road traffic congestion | Transport | Daily | Routine peak-hour events |
| Road works or street closures | Transport | Daily/Mid | Block-level = Daily; arterial = Mid |
| Parking shortages | Transport | Daily | Localised operational issue |
| Infrastructure failures (bridges, tunnels) | Transport | Mid/Large | Depends on criticality and duration |
| Fuel shortages | Transport | Large | Supply-chain disruptions |
| **Environment & Weather Disruptions** | | | |
| Extreme weather events (floods, heatwaves, snow) | Environment | Mid/Large | Extent and systemic consequence determine scale |
| Air quality alerts (smog, dust, pollution) | Environment | Daily/Mid | City-wide alerts = Mid; localized = Daily |
| Natural disasters (earthquake, storms, wildfires) | Environment | Large | Per EM-DAT inclusion criteria |
| Waterlogging after rainfall | Environment | Daily/Mid | Neighborhood = Daily; multi-district = Mid |
| Power outages caused by weather | Utilities | Daily/Mid | Cross-domain: weather trigger, utility impact |
| Closures of public spaces due to weather | Public Space | Daily/Mid | Park closures = Daily; city-wide = Mid |
| **Utilities & Connectivity Disruptions** | | | |

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*(Table S1.1 continued)*

| Survey Category | Taxonomy Domain | Typical Scale | Notes |
|---|---|---|---|
| Power outage (equipment failures, grid overloads) | Utilities | Daily/Mid/Large | Building = Daily; district = Mid; regional = Large |
| Water supply interruption | Utilities | Daily/Mid | Duration and extent determine scale |
| Digital connectivity outage (mobile/internet) | Utilities | Daily/Mid | ISP issues = Daily; infrastructure damage = Mid |
| Long delays in utility repairs | Utilities | Daily | Chronic degradation rather than acute event |
| **Public Space & Social Disruptions** | | | |
| Overcrowded public spaces | Public Space | Daily | Regular peak-period crowding |
| Excessive noise (construction, nightlife) | Public Space | Daily | Localized nuisance |
| Vandalism or property damage | Public Space | Daily | Unless widespread coordinated events |
| Restricted access to public spaces | Public Space | Daily/Mid | Event-specific closures |
| Safety concerns (poor lighting, unsafe areas) | Public Space | Daily | Chronic condition rather than event |

## Table S1.2: Social Media Risk Category Mapping

Table 2: Social media 11-category classification mapped to unified taxonomy

| **Social Media Category** | **Taxonomy Domain** | **Typical Scale** | **Mapping Rationale** |
|---|---|---|---|
| Transport | Transport | Daily/Mid | Direct domain alignment; includes traffic, PT delays, aviation |
| Security | Public Space | Mid/Large | Security incidents affect public space accessibility |
| Natural disaster | Environment | Large | Aligns with EM-DAT natural hazard group |
| Utilities | Utilities | Daily/Mid | Direct domain alignment; infrastructure failures |
| Health | Public Space | Mid/Large | Health emergencies constrain public space use (e.g., quarantine) |
| Crime | Public Space | Daily/Mid | Crime events affect perceived/actual public space safety |
| Social | Public Space | Daily/Mid | Social gatherings, protests affecting public space |
| Economic | Outside 4-domain taxonomy | – | Economic disruptions are indirect; not included in mobility taxonomy |
| Environment | Environment | Daily/Mid | Environmental degradation; distinct from natural disasters |
| Infrastructure | Transport/Utilities | Mid/Large | Context-dependent: transport infra maps to Transport; power/water maps to Utilities |
| Political unrest | Public Space | Large | Large-scale protests, civil disturbances |

**Note on "Economic" category:** Economic disruptions (e.g., inflation, currency crises) are systemic stressors that indirectly affect mobility through reduced purchasing power or service affordability. They are not included in the mobility-focused four-domain taxonomy but can be tracked separately as contextual factors in future longitudinal analysis.

## Table S1.3: EM-DAT Disaster Type Mapping

Table 3: EM-DAT disaster types mapped to unified taxonomy

| EM-DAT Disaster Type | Taxonomy Domain | Scale | Mobility Impact Examples |
|---|---|---|---|
| **Natural Disasters maps to Environment Domain** | | | |
| Flood | Environment | Large | Road/rail closures; PT rerouting; accessibility loss |
| Storm | Environment | Large | Infrastructure damage; service suspensions |
| Earthquake | Environment | Large | Bridge collapse; metro shutdown; cascading failures |
| Drought | Environment | Large | Water supply constraints affecting sanitation, firefighting |
| Wildfire | Environment | Large | Evacuation orders; air quality impacts on transport |
| Volcanic activity | Environment | Large | Air travel suspensions; road closures |
| Extreme temperature | Environment | Mid/Large | Heat: track deformation, PT capacity reduction. Cold: ice, snow |
| Mass movement (wet) | Environment | Mid/Large | Landslides blocking roads/rail |
| Mass movement (dry) | Environment | Mid/Large | Rockfalls, avalanches |
| Glacial lake outburst flood | Environment | Large | Sudden flooding; rare but catastrophic |
| **Technological Disasters maps to Utilities/Transport** | | | |
| Explosion (Industrial) | Utilities | Mid/Large | Infrastructure damage; local evacuations |
| Fire (Industrial) | Utilities | Mid | Smoke affecting visibility; local closures |
| Chemical spill | Utilities | Mid/Large | Hazmat zones; transport diversions |
| Gas leak | Utilities | Mid | Building evacuations; street closures |
| Oil spill | Utilities | Mid/Large | Maritime/coastal transport impacts |
| Collapse (Industrial) | Transport | Mid/Large | Building/bridge structural failures |
| Rail accident | Transport | Mid | Service disruptions; rerouting |
| Air disaster | Transport | Mid/Large | Airport closures; airspace restrictions |
| Water-related (maritime) | Transport | Mid | Port closures; shipping delays |

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*(Table S1.3 continued)*

| EM-DAT Disaster Type | Taxonomy Domain | Scale | Mobility Impact Examples |
|---|---|---|---|
| **Biological Disasters maps to Public Space** | | | |
| Epidemic | Public Space | Large | Quarantine; reduced public transport capacity; mobility restrictions |
| Infestation | Environment | Mid | Agricultural impacts; rare mobility effects |

**EM-DAT Inclusion Criteria:** Events in EM-DAT meet at least one of: (i) 10+ deaths; (ii) 100+ affected; (iii) declaration of emergency; (iv) call for international assistance. This threshold means EM-DAT captures primarily Large-scale events in our taxonomy.

## Table S1.4: Copernicus EMS Activation Type Mapping

Table 4: Copernicus EMS activation categories mapped to unified taxonomy

| CEMS Activation Type | Taxonomy Domain | Scale | Mapping Notes |
|---|---|---|---|
| Earthquake | Environment | Large | Aligns with EM-DAT; satellite damage assessment |
| Flood | Environment | Large | Most frequent CEMS activation type (2012-2025) |
| Storm | Environment | Large | Includes hurricanes, typhoons, cyclones |
| Wildfire | Environment | Large | 270 response records; 36 recovery (2012-2025) |
| Volcanic Activity | Environment | Large | Ash cloud monitoring; evacuation support |
| Mass Movement | Environment | Mid/Large | Landslides, avalanches |
| Industrial Accident | Utilities | Mid/Large | Chemical releases; explosions |
| Humanitarian Crisis | Public Space | Large | Refugee movements; conflict-induced displacement |
| Environmental Degradation | Environment | Mid | Slow-onset; differs from acute disasters |
| Other | (Context-dependent) | Mid/Large | Requires case-by-case assessment |

**CEMS Activation Phases:**

- **Preparedness:** Pre-event monitoring; risk assessment
- **Response (Rapid Mapping):** Immediate post-event damage assessment
- **Recovery:** Long-term reconstruction monitoring

All phases map to Large-scale in our taxonomy due to satellite activation thresholds.

## Table S1.5: Literature Coding Scheme Mapping

Table 5: Grounded theory codes from literature mapped to unified taxonomy

| GT Code/Category | Taxonomy Domain | Scale | Conceptual Link |
|---|---|---|---|
| **Disruption-Related Codes (n=1001 references)** | | | |
| Transport delays | Transport | Daily | Routine operational disruptions |
| Congestion | Transport | Daily | Peak-hour traffic |
| Infrastructure failure | Transport/Utilities | Mid/Large | Context-dependent |
| Pandemic impacts | Public Space | Large | COVID-19 mobility restrictions |
| Extreme weather | Environment | Mid/Large | Heat, cold, storms |
| Floods | Environment | Large | Urban flooding events |
| Earthquakes | Environment | Large | Seismic disruptions |
| **Adaptation-Related Codes (n=969 references)** | | | |
| Route choice | Transport | Daily | Tactical response to disruptions |
| Mode shift | Transport | Daily/Mid | Car $\leftrightarrow$ PT $\leftrightarrow$ bike $\leftrightarrow$ walk substitution |
| Telecommuting | Transport | Daily | Work-from-home as adaptation |
| Schedule adjustment | Transport | Daily | Off-peak travel to avoid disruption |
| **System adaptation codes (n=798 references)** | | | |
| Post-disruption learning | (All domains) | – | Conceptual category; not event-level |
| System improvement | (All domains) | – | Performance gains beyond baseline |
| Redundancy activation | (All domains) | Mid/Large | Dormant capacity utilization |
| Innovation acceleration | (All domains) | – | Technology adoption post-shock |

**Literature Coding Notes:**

- NVivo grounded theory analysis identified 16 major categories across 123 papers
- Many codes are conceptual (e.g., "complexity," "resilience") and do not map directly to disruption domains
- Event-specific codes (e.g., "heatwave impacts") were tagged with LitEvent_ID and transferred to Urban Event Catalogue
- Total coded references: 10,000+ across corpus

## Crosswalk Usage Examples

### Example 1: Survey Response Coding

**Raw response:** "Public transport delays due to snow"
**Coding steps:**

1. Survey category: "Public transport delays" describes the mobility *impact*, which maps to the **Transport domain**
2. Trigger: Snow, which maps to the **Environment domain**; the harmonised record therefore carries Environment as the trigger code and Transport as the impact code
3. Duration from context: ¡2 hours, localised, with no wider systemic consequence.
4. Final code: trigger Environment / impact Transport / Daily / Severity 3 (moderate, from survey Likert, following the mobility-impact anchors of manuscript Table 3)

### Example 2: Social Media Post Coding

**Tweet:** "#Athens metro closed after earthquake, buses rerouted"
**Coding steps:**

1. Social media category: "Natural disaster" maps to **Environment domain**
2. BUT: Post describes *mobility impact*, so also coded as **Transport domain**
3. Earthquake, as the triggering event, leads to a cross-domain cascade (Environment leading to Transport)
4. Scale: City-wide metro closure, corresponding to **Large scale**
5. Final codes: trigger Environment/impact Transport/Large/Severity 4; impact Transport/Large/Severity 3

### Example 3: EM-DAT Entry Coding

**EM-DAT record:** "Flood, Milan, illustrative date, 230 affected"
**Coding steps:**

1. EM-DAT type: Flood, which maps to **Environment domain**
2. Meets EM-DAT threshold (100+ affected), corresponding to **Large scale** by definition
3. Supplementary data (if available): "metro shutdown", coded as the Transport impact at Large scale
4. Severity follows the mobility-impact anchors of manuscript Table 3, not the affected-population count: the reported metro shutdown corresponds to Severity 4
5. Final code: trigger Environment / impact Transport / Large / Severity 4

### Example 4: Cross-Source Consistency Checks

**Scenario:** Same flood event appears in:

- Survey: "Extreme weather (flood)" maps to Environment/Mid (citizen perception)
- Social media: "Flood Milan" maps to Environment/Large (urgency level 4)
- EM-DAT: Milan flood entry maps to Environment/Large

**Cross-source comparison outcome:** Thematic agreement (all Environment domain) checks coding consistency. Scale discrepancy (Survey: Mid vs. Others: Large) suggests citizen experience may underestimate regional extent, which should inform Phase 2 survey design to query spatial extent explicitly.

## Crosswalk Maintenance and Versioning

### Version Control

This crosswalk is versioned to track evolution:

- **Version 1.0** (Current): Initial mapping based on pilot data
- **Version 1.1** (Planned): Incorporate operational refinements
- **Version 2.0** (Planned): Add new data sources (traffic sensors, IoT, etc.)

### Update Protocol

When adding new categories or refining mappings:

1. Document proposed change with rationale
2. Test on sample of 20+ events from new source
3. Check inter-coder reliability (Cohen's $\kappa \geq 0.75$)
4. Update this supplementary table with changelog entry
5. Disseminate the updated version to collaborators and users of the crosswalk