

Supplementary Materials

Supplementary Tables

Table S1. Detailed normalization specification for Vegvesen weather stations.

Field	Description
Raw input (examples)	metric_name, metric_value, timestamp, station/location references
Normalization steps	Parse and cast weather variables to numeric types; convert timestamps to UTC; keep physically plausible value ranges; map stations to urban zones for sub-area analysis
Normalized output (key fields)	source, timestamp (UTC), metric_name, metric_value, road_temperature, air_temperature, precipitation_intensity, wind_speed, relative_humidity, location/zone
Notes	Main meteorological backbone for cross-source temporal joins

Table S2. Detailed normalization specification for Oslo Bysykkel.

Field	Description
Raw input (examples)	Station status snapshots (station_id, available bikes/docks) + station metadata (capacity)
Normalization steps	Join status with station metadata; derive usage-oriented indicator; cast to numeric; harmonize timestamps to UTC; aggregate to minute level for analysis
Normalized output (key fields)	source, timestamp (UTC), station_id, metric_value (derived bike-usage indicator), optional coordinates
Notes	Represents system usage dynamics rather than direct trip logs

Table S3. Detailed normalization specification for Avinor flight operations.

Field	Description
Raw input (examples)	Repeated flight/event snapshots with uniqueID and operational fields
Normalization steps	Deduplicate to one record per uniqueID; align schema across files; harmonize timestamps to UTC

Normalized output (key fields)	source, timestamp (UTC), flight activity attributes, metric_value (event-level activity proxy)
Notes	Removes repeated snapshots of the same flight event

Table S4. Detailed normalization specification for Entur SIRI ET.

Field	Description
Raw input (examples)	trip_id, route_id, timestamp, start_date, start_time, stop_time_updates (arrival_delay, departure_delay)
Normalization steps	Explode stop-level updates; aggregate per trip; compute max arrival/departure delay; derive departure_timestamp from start_date + start_time; enforce plausible Unix-epoch bounds; apply deterministic time harmonization from service date and snapshot HHMMSS when required
Normalized output (key fields)	source, trip_id, route_id, timestamp, departure_timestamp, max_arrival_delay_sec, max_departure_delay_sec
Notes	Produces trip-level delay features

Table S5. Detailed normalization specification for Vegvesen travel times.

Field	Description
Raw input (examples)	Corridor/link travel-time records (period_start, free_flow/travel-time fields)
Normalization steps	Convert temporal fields to UTC; truncate to minute where needed; apply day-window filtering
Normalized output (key fields)	source, period_start/minute, free_flow_travel_time_sec, free_flow_speed_kmh, related travel-time metrics
Notes	Provides traffic performance context

Table S6. Detailed normalization specification for Vegvesen traffic situations.

Field	Description
Raw input (examples)	Event/status feed with type and time information
Normalization steps	Normalize event time to minute resolution; aggregate event counts by minute and type; harmonize to UTC
Normalized output (key fields)	source, minute, situation_type, event_count, optional location references

