



MARKOPOLO

Noise and/or ultrafine particulate matter induced cerebral and cardiovascular damage: novel insights from experimental and epidemiological brain-heart axis biomarkers and computational models

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Report on UFP measurements and relevant predictors

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SUMMARY

This deliverable presents the midterm progress on UFP measurements and relevant predictors (predominantly Task 4.3). This task aims to improve the assessment of individual exposure to ultrafine particles (UFP) and other environmental pollutants for population-based epidemiological studies within MARKOPOLO. During the reporting period, extensive outdoor mobile monitoring campaigns were successfully completed across Switzerland, Denmark, and Lithuania, generating harmonized, high-resolution measurements of UFP and co-pollutants. In parallel, historical UFP measurements from stationary monitoring networks and previous mobile campaigns have been compiled to extend temporal coverage and support long-term exposure assessment. Preparatory work for high-resolution spatiotemporal exposure modelling has focused on developing harmonized predictor datasets describing traffic, land cover, meteorology, vegetation, population, and other environmental characteristics. In addition, an indoor air pollution measurement campaign has been initiated to quantify the influence of outdoor pollution, residents' behaviours, and dwelling characteristics on indoor concentrations of UFP, PM_{2.5}, NO₂, BTEX, temperature, and humidity. Finally, the deliverable summarizes the scientific outputs generated to date, including one published paper and three manuscripts currently in preparation.

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1 INTRODUCTION

1.1 Purpose and Scope

This document describes the midterm progress of the UFP exposure assessment activities within MARKOPOLO, including outdoor mobile monitoring campaigns, compilation of historical UFP measurements, preparation for spatiotemporal exposure modelling, indoor air pollution measurements, and the scientific outputs generated during the reporting period.

1.2 References to other MARKOPOLO Documents

- MARKOPOLO DoA
- Appendix 1: Study protocol describing the harmonisation framework and exposure assessment strategy across SNC and DNC
- Appendix 2: Predictors derived for Swiss and Danish spatiotemporal UFP models

1.3 Definitions, Abbreviations and Acronyms

Table 1 List of Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
SNC	Swiss National Cohort
UFP	Ultrafine particles
PNC	Particle number concentration

2 UFP MEASUREMENTS & RELEVANT PREDICTORS

2.1 Objectives (Task 4.3)

The overarching aim of Task 4.3 is to improve the assessment of individual exposure to ultrafine particles (UFP) and other environmental pollutants in population-based epidemiological studies. Accurate characterization of environmental exposures is essential for reducing exposure misclassification and strengthening the assessment of long-term health effects and environmental inequalities. To achieve this, the task combines new and historical monitoring data with advances in exposure modelling to provide harmonized, high-resolution exposure estimates across participating countries. In addition, indoor and outdoor measurements are conducted to improve understanding of the factors determining personal exposure, including the influence of outdoor pollution, residents' behaviours and activities, and building characteristics. Together, these activities provide the foundation for refined exposure assessment and subsequent analyses of socioeconomic differences in environmental exposures and their impacts on population health.

The main objectives related to UFP measurements and relevant predictors in Task 4.3 were:

1. **Outdoor mobile monitoring:** Conduct environmental exposure measurements by performing outdoor mobile monitoring campaigns for ultrafine particles (UFP) and related air pollutants in Switzerland, Denmark, and Lithuania.
2. **Historical UFP measurements:** Compile and harmonize environmental exposure measurements by combining newly collected and historical UFP measurements from stationary sites (2000–2024) and previous mobile measurement campaigns (2019–2024) to support long-term exposure assessment.
3. **Spatiotemporal modelling:** Prepare the datasets, predictor variables, and measurement inputs required for the development and validation of high-resolution spatiotemporal exposure models in collaboration with WP7, enabling the generation of harmonized, address-level exposure estimates for subsequent epidemiological analyses.
4. **Indoor air pollution exposure:** Characterize indoor exposure determinants by quantifying the contribution of outdoor pollution, residents' behaviours and activities, and building characteristics to indoor concentrations of UFP, PM_{2.5}, NO₂, BTEX, temperature, and humidity.

2.2 Outdoor mobile monitoring

During the reporting period, extensive outdoor mobile monitoring campaigns were successfully conducted across Switzerland, Denmark, and Lithuania to generate high-resolution measurements of ultrafine particles (UFP) and co-pollutants. These campaigns form the empirical basis for the development of harmonized spatiotemporal exposure models and will support improved individual exposure assessment in the participating population cohorts.

A harmonized measurement setup was used for all measurements in all countries, in collaboration with the University of Utrecht. Measurements were conducted using an electric monitoring vehicle equipped with instruments recording particle number concentration (PNC; UFP), lung-deposited surface area, PM_{2.5}, NO₂, black and brown carbon, and CO₂ at 1-second temporal resolution. Across all three countries, standardized monitoring protocols (**Table 1**) ensure comparability of measurements and provide a robust foundation for the development and validation of harmonized exposure models and subsequent epidemiological analyses.

In Switzerland, three nationwide measurement campaigns covering the warm, cold, and intermediate seasons were completed between June 2025 and April 2026. The campaigns covered more than 17,000 km of the Swiss road network, including all major cities and numerous smaller towns, providing a unquented dataset for national UFP exposure modelling.

In Denmark, mobile monitoring campaigns were completed across Zealand during winter, spring, and summer 2025–2026 using comparable instrumentation and measurement protocols. Together with historical mobile and stationary measurements, these data will contribute to the development of long-term UFP exposure models harmonized with those developed for Switzerland.

In Lithuania, mobile monitoring campaigns were completed in Kaunas during the autumn 2025 and winter 2026 seasons. More than 100 hours of measurements were collected over approximately 2,800 km of urban roads. In addition, a permanent reference monitoring station is being used to support land-use regression (LUR) modelling and exposure estimation at participants' residential addresses.

Table 1. Overview of outdoor mobile monitoring campaigns conducted during the reporting period.

Country	Monitoring periods	Area covered
Switzerland	Summer 2025 (16 Jun–9 Aug); Winter 2026 (14 Jan–28 Feb); Spring 2026 (1 Mar–27 Apr)	Nationwide (all major cities and numerous smaller towns; >17,130 km road network)
Denmark (Zealand)	Winter 2025 (13 Nov–16 Dec); Spring 2026 (13–31 May); Summer 2026 (1–25 Jun)	Zealand (major towns and surrounding areas)
Lithuania (Kaunas)	Autumn 2025 (completed); Winter 2026 (completed)	Kaunas urban area (~2,815 km monitored)

2.3 Historical UFP measurements

To improve the temporal coverage of UFP exposure assessment within MARKOPOLO, historical measurements from existing stationary monitoring networks and previous mobile monitoring campaigns (**Table 2**) are being compiled and harmonized with newly collected measurements. Together, these datasets will provide the empirical basis for developing retrospective exposure models covering the study period from 2000 onwards.

Previous measurement campaigns conducted using comparable monitoring protocols are particularly valuable, as they extend the temporal coverage of the MARKOPOLO measurement campaigns. These include:

- Copenhagen (2018–2020): Mobile monitoring campaign conducted as part of the EXPANSE project (Kerckhoffs et al., 2022^{1,2}).
- Basel-Stadt and Basel-Landschaft (2021–2022): Mobile monitoring campaign conducted as part of the EXPANSE project (Vlaanderen et al., 2021³).

Table 2. Historical UFP measurements relevant for MARKOPOLO

Country	Type	Data owner	Time span	Status
Switzerland	Stationary monitoring	NABEL monitoring network Switzerland (5 stations)	2003-2026	Data available
	Mobile monitoring platform	University of Utrecht, the Netherlands, collected for EXPANSE project, 53 driving days	2021-09-12 until 2021-11-29 and 2022-04-11 until 2022-06-10	Data Transfer Agreement signed
Denmark	Stationary monitoring	Danish Municipal UFP monitoring network (3 stations)	2020-2025	Data available
		Danish National UFP monitoring network (4 stations)	2001-2024	Data available in July 2026 for 2025
	Mobile monitoring platform	University of Utrecht, the Netherlands, collected for EXPANSE project, 232 driving days	2018-10-15 until 2020-03-15	Data Transfer Agreement signed
Lithuania	Stationary monitoring	Vytautas Magnus University, Kaunas; collection for MARKOPOLO project	2025-2026	Data available

Historical UFP datasets have been identified and are currently being compiled from stationary monitoring networks and previous mobile monitoring campaigns in Switzerland, Denmark and Lithuania. Data transfer agreements have been completed where required, and most datasets have been received. Prior to integration into the modelling framework, historical measurements will undergo standardized quality assurance at partner institutions as well as validation and post-hoc calibration where necessary to ensure consistency with the MARKOPOLO measurement campaigns. The harmonized historical and newly collected datasets will be used as input for the development of spatiotemporal UFP exposure models.

¹ Kerckhoffs, J.; Khan, J.; Hoek, G.; Yuan, Z.; Ellermann, T.; Hertel, O.; Ketzel, M.; Jensen, S. S.; Meliefste, K.; Vermeulen, R. Mixed-Effects Modeling Framework for Amsterdam and Copenhagen for Outdoor NO₂ Concentrations Using Measurements Sampled with Google Street View Cars. *Environ. Sci. Technol.* **2022**, 56 (11), 7174–7184,

² Kerckhoffs, J., Khan, J., Hoek, G., Yuan, Z., Hertel, O., Ketzel, M., Jensen, S.S., Al Hasan, F., Meliefste, K. and Vermeulen, R., 2022. Hyperlocal variation of nitrogen dioxide, black carbon, and ultrafine particles measured with Google Street View cars in Amsterdam and Copenhagen. *Environment international*, 170, p.107575.

³ Vlaanderen, J., De Hoogh, K., Hoek, G., Peters, A., Probst-Hensch, N., Scalbert, A., Melén, E., Tonne, C., De Wit, G.A., Chadeau-Hyam, M. and Katsouyanni, K., 2021. Developing the building blocks to elucidate the impact of the urban exposome on cardiometabolic-pulmonary disease: The EU EXPANSE project. *Environmental Epidemiology*, 5(4), p.e162.

2.4 Spatiotemporal modelling

The objective of the spatiotemporal modelling component is to develop high-resolution exposure models for ultrafine particles (UFP) that can be applied retrospectively to residential address histories in the participating cohorts. During the reporting period, preparatory work focused on compiling, harmonizing, and deriving predictor variables required for model development.

UFP concentrations are influenced not only by emission sources, but also by atmospheric dispersion, deposition processes, and meteorological conditions. Consequently, predictor variables were selected to represent the main determinants of spatial and temporal variability in UFP concentrations. These include variables describing geographical location, traffic intensity and infrastructure, land cover and land use characteristics, meteorological conditions (e.g. wind speed and direction, temperature, precipitation, radiation, and atmospheric stability), population density, vegetation, altitude, temporal patterns, and other environmental characteristics.

A harmonized predictor database has been developed for both Switzerland and Denmark to ensure comparable model development across countries. Predictor datasets have been processed to common spatial and temporal resolutions and linked to the mobile monitoring data collected during the measurement campaigns described in Section 2.3. This harmonized framework provides the basis for the subsequent development and validation of machine-learning-based spatiotemporal UFP models.

A detailed description of all predictor variables, their sources, and derivation methods is provided in **Appendix 2**: Predictors derived for Swiss and Danish spatiotemporal UFP models.

2.5 Indoor air pollution exposure

The MARKOPOLO indoor/outdoor project combines real-time air quality monitoring with participant-contributed household activity data to investigate how outdoor concentrations, residential building characteristics, and everyday behaviours influence indoor air pollution. The project engaged 60 Swiss households, each contributing data for two one-week periods during the warm and cold seasons. At each home, air quality sensors were deployed simultaneously indoors and outdoors to measure UFP number concentration (PNC), PM_{2.5}, CO₂, temperature and relative humidity in real-time. In addition, we measure NO₂ and BTEX (benzene, toluene, ethylbenzene and xylenes (including o-, m-, and p-xylene)) using passive measurement tubes during the same 1-week period.

To link concentration dynamics with occupant activities, participating households completed time-activity diaries at 10-minute resolution, documenting activities known to influence indoor particle levels, including cooking, candle burning, fireplace use, and window opening. Sixty households were recruited across four categories: 16 residences with indoor fireplaces, 16 Minergie-certified (energy-efficient) buildings, 18 households located along heavily trafficked roads, and 18 control households, with seven households belonging to two or three categories.

Data collection is ongoing until August 2026. Preliminary results show pronounced short-term increases in indoor UFP concentrations associated with combustion-related activities, particularly cooking and candle burning. Indoor PNC was significantly associated with outdoor

PNC, and this influence was stronger if the windows were open. Indoor combustion-related activities, particularly woodburning, cooking and candle burning are strongly associated with short-term increases in indoor PNC. After activities ended, concentrations stayed elevated significantly for 2-6 hours.

The study highlights the value of combining real-time sensor measurements with citizen-contributed activity information to understand peaks in residential air pollution under real-life conditions, which would be obscured in daily/hourly averages. Moreover, it supports public awareness and exposure-reduction strategies in the home.

3 OUTPUT SO FAR

The activities undertaken within Task 4.3 have already resulted in scientific outputs and are expected to generate several additional publications during the project. Together, these manuscripts document the methodological developments required for improved ultrafine particle (UFP) exposure assessment, from measurement campaigns and predictor development to spatiotemporal modelling and indoor exposure characterization.

The first project-related publication has already been published in CHIMIA⁴, providing an overview of the MARKOPOLO project and highlighting its objectives, scientific approach, and expected impact on understanding the health effects of environmental pollution. This publication introduces the role of improved environmental exposure assessment within the project and outlines the contribution of the Swiss partners.

Building on this overview, three scientific manuscripts are currently in preparation:

- *"Nationwide Mobile Monitoring of Ultrafine Particles in Switzerland"* describes the design, implementation, and evaluation of the nationwide mobile monitoring campaigns, providing one of the largest empirical UFP datasets collected in Switzerland.
- *"A Measurement-Based National Spatiotemporal Model for Ultrafine Particle Number Concentration in Switzerland"* presents the development and validation of a high-resolution spatiotemporal UFP exposure model based on harmonized mobile and historical monitoring data together with geographic, meteorological, and environmental predictors. We aim to publish a similar model for Zealand, Denmark ultimately. Both models will provide retrospective address-level exposure estimates for epidemiological analyses within MARKOPOLO.
- *"Ultrafine Particles in Swiss Households: Insights into How Residential Behaviour and Dwelling Characteristics Influence Indoor Air Pollution"* reports findings from the ongoing indoor air pollution measurement campaign. The study investigates how indoor concentrations of UFP and co-pollutants are influenced by outdoor pollution, residents' activities and behaviours, and dwelling characteristics, thereby improving understanding of determinants of personal exposure in residential environments.

⁴ Eeftens, M., Twomey, E.P., Streit, F. and Rössli, M., 2026. Airborne Ultrafine Particles: Real-life Exposure Patterns, Epidemiological Evidence and Regulatory Responses in Switzerland and Beyond. *Chimia*, 80(1-2), pp.64-70.

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Appendix 1

Ethics and harmonization of exposures, covariates and outcomes in DNC and SNC

ETHICS

Denmark: According to Danish law (Section 14 of the Act on Research Ethics Review of Health Research Projects and Health Data Science Research Projects), purely registry-based studies do not require ethics committee approval or informed consent.

Switzerland: the MARKOPOLO project involves handling personal and sensitive health data, which is subject to strict ethical and legal restrictions, including GDPR and Swiss data protection laws. All data sharing activities are reviewed to ensure full compliance with ethical approvals, institutional data protection policies, and a data transfer agreement for the Swiss National Cohort which covers MARKOPOLO explicitly (Datenschutz- und Verknüpfungsvertrag “Zusammenhang zwischen der ursachenspezifischen Sterblichkeit und dem Umwelt-Exposom“, Data protection and linkage agreement “Association between cause-specific mortality and the environmental exposome”).

HARMONISATION

Data management plans for both DNC and SNC were harmonized and submitted in M6 of the project, including chapters on FAIR data, increase of data re-use, allocation of resources, data security and ethics.

Exposures

Air pollution

Particle Number Concentration (PNC) was measured as part of mobile monitoring campaigns in all of Zealand (Denmark) and all of Switzerland. Ultrafine particles (UFP) were measured as PNC at 1-second intervals using an EPC 3787 instrument, together with co-pollutants including PM_{2.5}, NO₂, and black carbon.

- Switzerland:
 - Summer 2025 (warm season): 16 June – 9 August (55 days)
 - Winter 2026 (cold season): 14 January – 28 February (46 days)
 - Spring 2026 (intermediate season): 1 March – 27 April (58 days)
- Denmark
 - Winter 2025 (cold season): 13 November – 16 December (29 days)
 - Spring 2026 (intermediate season): 13 May – 31 May (16 days)
 - Summer 2026 (warm season): 1 June – 25 June (20 days)

Measurements covered all major towns and a large number of smaller towns in the region.

Long-term exposure to air pollution co-pollutants NO₂, PM_{2.5} and PM₁₀ is available annually at 25m x 25m resolution from the exposome maps portal (<https://exposome.uu.nl>) for all of Europe, including Denmark and Switzerland (from the Expanse project). Data has been retrieved for both cohorts.

Short-term daily exposure to air pollution co-pollutants (for analyses of short-term health associations) is available for NO₂ (de Hoogh et al, 2019) and PM_{2.5} (de Hoogh et al, 2018). Daily O₃ and temperature are also for Switzerland and will be explored (Sun et al., submitted).

For further information, see D4.9 (Report on UFP measurements and relevant predictors).

Transportation noise

- Road traffic noise: Exposure to residential road traffic noise has been estimated in both cohorts at the most and least exposed facades for each address/building using comparable, acoustical models and input data (Denmark: The Nordic Prediction Method (Thacher et al, 2020); Switzerland: sonROAD model (Heutschi, 2004) and StL-86 propagation model (BAFU, 1987). Inspection of the distribution of noise in the two cohorts showed very similar distributions and exposure ranges.
- Railway noise: Noise from trains was calculated at all residential addresses adjacent to rail tracks in Denmark and Switzerland at the most exposed facade using comparable acoustical models and input data. In Denmark, the Nord2000 noise model was applied (Plovsing and Kragh 2006) and in Switzerland noise emissions were calculated using sonRAIL (Thron and Hecht, 2010). Inspection of the distribution of noise in the two cohorts showed similar distributions and exposure ranges.
- Aircraft noise: Aircraft noise for long-term exposure assessment at the major, international airport in Denmark (Copenhagen Airport) and Switzerland (Zürich Airport) has been obtained/calculated using similar methods in the two cohorts.

Green and blue space

Harmonized derived variables are available for all of Europe, including both Denmark and Switzerland, through the Expanse portal. Data includes distance to nearest green space using the harmonized EEA dataset CORINE ([Corine Land Cover](#)), mean/median normalized difference vegetation index (NDVI) in 300, 500, 1000 buffers, and distance to the nearest blue space. In addition, land use maps are available for Denmark ([Basemap](#)) and Switzerland ([swissTLM3D](#)) in high resolution.

Light at night

Light at night is available in buffers of 300, 500 and 1000m from the Expanse project through the exposome maps portal <https://exposome.uu.nl>. We will explore this exposure, but use it carefully, because it was found to be highly correlated to population density, but not a good proxy for indoor evening or nighttime personal exposure as measured a population of 12-y-old children in the Netherlands (Huss et al, 2019). This study recommended that studies planning to evaluate potential risks from light at night should consider modifying factors, such as curtains and indoor lighting and the use of electronic devices and should include performing indoor or personal measurements to validate any exposure proxies, which is not feasible or anticipated in either DNC or SNC.

Co-variates

We have harmonized covariate data in the two cohorts as follows:

Description	Format	Description, Denmark	Description, Switzerland
Age	Continuous	From follow-up (2000) onwards	From follow-up (2010) onwards
Sex	Categorical	Male, Female	Male, Female
Cohabiting	Categorical	1 = Married or cohabiting 2 = Live alone (and Widow(er), Divorced; or not married)	1 = Married or cohabiting (=couple with and without children) 2 = Live alone (and Widow(er), Divorced; or not married)
Highest completed education	Categorical	1) Compulsory education or less 2) Upper secondary level 3) Tertiary level education	1) Compulsory education or less 2) Upper secondary level 3) Tertiary level education 4) Not known
Country of birth	Categorical	1 = Denmark 2 = not Denmark	1 = Switzerland 2 = not Switzerland
Income, individual	Categorical	In 5 calendar-year- and sex-specific categories (categories of equal size, quintiles).	Not available for Switzerland
Area-level SES	Continuous	The following SES variables at parish level are available: 1. Proportion of inhabitants with low income 2. Proportion of unemployed inhabitants 3. Proportion of inhabitants with compulsory education or less	The following SES variables are available: 1. Composite socio-economic position index considering 50 closest households (based on composite median rent per square meter of living space, type of occupation and educational level of the household head, and number of persons per room) (Panczak et al., 2023, 2012) 2. Proportion of unemployment at community level

Associations between exposures and socioeconomic status are shown in deliverables D4.7 and D4.8.

Outcomes

Adults

Mortality

1. We will identify individuals in SNC and DNC who died during follow-up using national Registers of Causes of Death coded according to the International Classification of Disease version 10 (ICD10). We will include natural causes of death as outcome, and censor participants at death from external causes (ICD10 S-Z). Besides all natural-causes mortality, we will define mortality due to cardiovascular disease (CVD, ICD10: I00-I99), ischemic heart disease (IHD, ICD10: I20-I25), stroke (ICD10: I60-I64), respiratory diseases (ICD10: J00-J99), pneumonia (J12-J18), chronic obstructive pulmonary diseases (COPD, ICD10: J40-J44) and cancer (ICD10: C00-C97).

2. *CNS tumors (Switzerland)*

Using death records from the Swiss National Cohort with malignant brain tumor as the primary cause of death (ICD-10 codes C71/0–C71/9) between 2010 and 2025.

Incident cardiovascular disease

For Denmark, we will use the primary hospital discharge diagnoses and underlying causes of death from the Danish National Patient Register and the Danish Register of Causes of Death to define the following CVDs:

Disease outcome	ICD-10
Stroke	I60-69
Ischemic heart disease	I20-25
Heart failure / Cardiac arrest	I50, I46
Atrial fibrillation	I48
All cardiovascular	I00-99
MACE (major adverse cardiovascular events)	IHD (I20-25) or stroke (I60-69) hospital admission or death

For Switzerland, stroke cases will be drawn from the SNC and defined as all deaths registered with stroke as the primary cause of death (ICD-10 codes I60–I69) between 2010 and 2025. Since UFP concentrations will be known spatiotemporally, we will be able to evaluate the association with daily incident stroke cases using a case-crossover analysis. We will further distinguish haemorrhagic strokes (I60-I62) and ischemic strokes (I63). Similarly, data on strokes (fatal and non-fatal) will be obtained from the Swiss Stroke Registry, with additional confounders related to lifestyle available, including smoking status, regular medication taken, medical history (including previous strokes), blood pressure and BMI.

Children

Perinatal outcomes

For Denmark, information on birth weight, gestational age and maternal smoking will be obtained from the Danish Medical Birth Registry. Based on these data, we will define various perinatal outcomes, such as small for gestational age (birth weight < 10th percentile for gestational age and sex) and low birthweight (birth weight >2,500 gram among infants born at or after 37 weeks).

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Appendix 2: Predictors derived for Swiss and Danish spatiotemporal UFP models

Predictor Class	Predictor	Type	Source	Unit	Calculation	Spatial Resolution	Temporal Resolution	Available Data Period
Geo location	Longitude	Spatial	Derived	m	Derived		NA	
	Latitude	Spatial	Derived	m	Derived		NA	
Traffic	Average daily traffic volume person transport	Spatio-temporal	Danish Cancer Institute and Swiss TPH (local variables)	vehicle*m	weighted buffer of raster	Street segments	NA	
	Average daily traffic volume cargo transport	Spatio-temporal		vehicle*m	weighted buffer of raster	Street segments	NA	
	Road density by road type (OSM) (Motorway Primary Secondary, Tertiary, Residential)	Spatio-temporal	Open Street Map (OSM)	street*m/cell	weighted buffer of motorway 250m		NA	
				street*m/cell	weighted buffer of motorway 500m		NA	
				street*m/cell	weighted buffer of motorway 1000m		NA	
				street*m/cell	weighted buffer of primary road 250m		NA	
				street*m/cell	weighted buffer of primary road 500m		NA	
				street*m/cell	weighted buffer of primary road 1000m		NA	
				street*m/cell	weighted buffer of sec/ter/res road 250m		NA	
				street*m/cell	weighted buffer of sec/ter/res road 500m		NA	
				street*m/cell	weighted buffer of sec/ter/res road 1000m		NA	

Predictor Class	Predictor	Type	Source	Unit	Calculation	Spatial Resolution	Temporal Resolution	Available Data Period
Land Cover	Water (Corine Reclassification x-y)	Spatial	Corine Landcover 2018, Copernicus Land Monitoring Service WeKEO - <i>alternatively DK Basemap04</i>	fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018
	Urban (Corine Reclassification x-y)	Spatial		fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018
	Agriculture (Corine Reclassification x-y)	Spatial		fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018
	Forrest (Corine Reclassification x-y)	Spatial		fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018
	Industry (Corine Reclassification x-y)	Spatial		fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018

Predictor Class	Predictor	Type	Source	Unit	Calculation	Spatial Resolution	Temporal Resolution	Available Data Period
Land Cover (continued)	Aiport (Corine Reclassification x-y)	Spatial	Corine Landcover 2018, Copernicus Land Monitoring Service WeKEO - <i>alternatively DK Basemap04</i>	fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018
	Port (Corine Reclassification x-y)	Spatial		fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018
	Barren (Corine Reclassification x-y)	Spatial		fraction	weighted buffer of raster 250m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100m x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100m x 100m	NA	2018
Weather	Wind East-West	Spatio-temporal	ECMWF/Copernicus Climate Data Store "ERA5-Land hourly data from 1950 to present"	m/s	NA	9km x 9km	hourly	1950-2025
	Wind North-South	Spatio-temporal		m/s	NA	9km x 9km	hourly	1950-2025
	Dewpoint temperature (2 meters)	Spatio-temporal		°K (C?)	NA	9km x 9km	hourly	1950-2025
	Mean Sea Layer Pressure	Spatio-temporal		kPa	NA	9km x 9km	hourly	1950-2025
	Boundary layer heigth	Spatio-temporal		m	NA	31km x 31km	hourly	1950-2025
	Total cloud coverage	Spatio-temporal		fraction	NA	31km x 31km	hourly	1950-2025
Predictor Class	Predictor	Type	Source	Unit	Calculation	Spatial Resolution	Temporal Resolution	Available Data Period

Weather (continued)	Total precipitation	Spatio-temporal		mm	sum of hourly precipitation (mm) in a day	9km x 9km	hourly	1950-2025
	Relative humidity	Spatio-temporal		%	derived by dewpoint temp and temp	9km x 9km	hourly	1950-2025
Population	Population Density	Spatio-temporal	The Humanitarian Data Exchange	n	weighted buffer of raster 250m	30m x 30m	NA	2018
				n	weighted buffer of raster 500m	30m x 30m	NA	
				n	weighted buffer of raster 1000m	30m x 30m	NA	
Vegetation	Normalized Difference Vegetation Index	Spatial	NDVI, Copernicus Land Monitoring Service WeKEO	fraction	weighted buffer of raster 250m	100 x 100m	NA	2018
				fraction	weighted buffer of raster 500m	100 x 100m	NA	2018
				fraction	weighted buffer of raster 1000m	100 x 100m	NA	2018
Altitude	Altitude	Spatial		m	NA	10m x 10m	NA	2025
Time	Hour of the day	Temporal	Derived					
	Hour of the day	Temporal	Derived		cosine transformation of days 1-7	NA	daily	
	Day of the week	Temporal	Derived	category	NA	NA	daily	
	Day of the year	Temporal	Derived					
	Day of the year	Temporal	Derived		cosine tranformation of days 1 - 365 (366)	NA	daily	
	School holidays	Temporal	Derived	category	NA	NA	daily	2002-2026
	Public holidays	Temporal	Derived	category	NA	NA	daily	
Other	Maritime Traffic		http://aisdata.ais.dk/					