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Spatio-temporal population exposure modeling for German cities

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In disaster risk assessments, spatial population data are fundamental for determining exposure and social vulnerability. Traditionally, these analyses rely on static datasets, such as census records or population density maps. While accurate for representing nighttime distribution, these static models fail to capture the high levels of human mobility during the day. This can lead to significant under- or overestimations of the affected population, particularly in the event of sudden-onset disasters (e.g., flash floods, earthquakes, or critical infrastructure failure).

To address this, high-resolution temporal data are required. However, existing approaches often rely on real-world measurements, such as cell phone data or GPS positions. Such data is usually purchased from data companies, limiting its utility for both research and emergency management.

This study presents a spatio-temporal population model, initially developed for Germany's rich open data landscape, but with potential to be transferred to similar regions in the future. Using the city of Cologne as a primary test site, the model generates population maps for different time intervals throughout a typical weekday. The methodology employs iterative dasymetric mapping, integrating publicly available socio-demographic data, detailed building footprints, and the "Mobility in Germany" study. This approach ensures high transferability to other German metropolitan areas without requiring proprietary data.

The model estimates the number of individuals in each building across seven distinct time intervals (e.g., 8 am – 10 am, 10 am – 1 pm) and further disaggregates the population into socioeconomic groups (e.g., students, elderly). The results were validated against three independent datasets: emergency call volumes, the ENACT POP dataset, and mobile phone positioning data.

The model results enable refined disaster risk analysis by incorporating the temporal component of hazards and the corresponding population exposure. In the case of Cologne, this results in areas, such as the inner City at midday, with up to 5 times more exposed citizens than exposure

analyses that rely on static data. Following the principles of Open Science, both the model code and the resulting datasets will be made publicly accessible to facilitate dynamic population assessments in other contexts.