Healthy smart cities – development of healthcare- focused urban analytics models and decision making tools to reduce heat waves impact on public health

Abstract

The contents of this thesis are designed to mitigate the public health impacts of heat, specifically within the context of transitioning toward healthier smart cities. Using Italy and the city of Milan as case studies, the research adopts a holistic approach to explore the key determinants of heat-health risks, i.e., population vulnerability, environmental hazards, and residents' exposure. Developed methodologies are characterized by their flexibility, offering both academic contributions and practical applications for addressing the increasing public health challenges posed by rising temperatures.

The thesis begins by proposing a novel municipality-level SDG3 index for Italy, addressing disparities in data availability and spatial granularity while identifying significant regional variations in public health performance. Despite the limitations in data quality and temporal accuracy, the SDG3 index provides a valuable tool for local policymakers to compare municipalities and tailor public health interventions.

A systematic review of the literature on heat effects on cardiovascular (CV) health reveals substantial heterogeneity in the definitions of heat used across studies, with a total of 21 definitions found in 54 articles. To address this inconsistency, the thesis proposes a guideline for standardizing heat definitions in health research by integrating well-established statistical techniques, such as distributed lag non-linear model and Poisson regression.

Using Milan as a case study, the research further investigates the impact of heat on CV ambulance dispatches. By applying the proposed heat definition guideline to data from May to September in the years 2017-2022, the analysis identifies the 95^{th} percentile of annual mean daily temperature distribution as the proper heat threshold for Milan. The corresponding relative risk is assessed at 1.11, with 95% confidence interval equal to 1.09-1.14.

The thesis also explores the socio-urban characteristics that influence CV vulnerability to heat, using machine learning techniques and spatial regression models. The research produces a socio-urban vulnerability index, which is combined with medical data to create a vulnerability map, highlighting high-risk areas, found as encompassing 18 of 86 Milan's districts, where more than 300,000 people reside.

The final phase of the research involves the use of artificial intelligence to forecast daily CV emergencies, with a focus on meteorological parameters. The application of explainable artificial intelligence, derived from Shapley values, enhances transparency in the model's decision-making process, revealing that while temperature has minimal influence on the predictions on most days, its impact sharply increases during heat days (R^2=0.79).

This thesis offers significant contributions to the development of smart, resilient cities that proactively safeguard public health in the face of climate change, providing tangible insights to the emergency medical services, urban planners and local policymakers, as well as methodological solutions advancing the state-of-the-art. However, it also acknowledges several limitations, including data temporal misalignment, the use of relative indices, and the exclusion of certain urban areas. Future research should focus on improving data integration, enhancing spatio-temporal resolution, and expanding interdisciplinary collaboration.