From Step Scale to Urban Scale: Toward Multi-Scale Walkability Indicators Based on Real Walking Experience

Scientific context and positioning

Walking is a central lever for sustainable mobility and public health policies. Yet, the assessment of urban walkability[1] still relies mainly on macroscopic indicators describing the structure of cities and their street and public transport networks (density, connectivity, accessibility), without taking into account the actual characteristics of spontaneous pedestrian trips in the city, nor how pedestrians perceive their environment while moving.

Within the AAU-CRENAU laboratory, several recent doctoral and postdoctoral works have helped enrich walkability analysis by introducing situated approaches to urban space from the pedestrian point of view [1–9]. These works have made it possible to link specific elements of the urban environment to walking practices, and to explore the transferability of these indicators toward operational tools, notably for local authorities and planning stakeholders. They have gone beyond strictly macroscopic approaches to walkability by proposing high-resolution and situated readings of urban space from the pedestrian viewpoint, grounded in visual perception and measurable environmental indicators. While they have laid the methodological foundations required for a change of scale, the effective move toward a fully multi-scale analysis of walkability still remains to be built.

The proposed PhD is part of the ANR CITY-STEP project (ANR-25-CE22-2248), which aims to renew the evaluation of urban walkability by integrating the analysis of walking in real urban conditions, as opposed to laboratory-based walking studies that do not reflect the effective dynamics of urban walking. Building on in situ experiments and on the use of data from sensors worn by pedestrians, CITY-STEP seeks to better understand how urban morphology, spatial configuration, and environmental factors (such as climatic conditions, for example) influence walking at the step scale. The project is based on a partnership between three actors: the AAU-CRENAU laboratory, where this PhD will be conducted; the GEOLOC laboratory (Université Gustave Eiffel), which leads a second PhD dedicated to modelling the walking model; and Nantes Métropole, a territorial partner providing expert insight into operational issues. This PhD will interact closely with that second PhD as well as with the transversal postdoctoral position planned between the two laboratories within the project, and will more broadly take place within a collaborative effort involving all researchers engaged in CITY-STEP, across both partner laboratories, as well as Nantes Métropole.

In this context, the specific objective of the PhD is to contribute to the construction of a multi-scale rating (similar to a Nutri-Score, for example) of walkability in urban environments, by articulating fine-grained observations from real walking on site with morphological, environmental, and perceptual descriptors of urban space. The aim is therefore to achieve a methodological articulation from the local scale of experiments (step, street segments) to more

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[1] Walkability refers to the extent to which an urban environment encourages, facilitates, and makes walking enjoyable as an everyday mode of travel. It is not limited to the physical conditions of movement alone, but also encompasses the full range of spatial, functional, environmental, and perceptual characteristics that shape the pedestrian experience.

global representations of walkability (street, neighbourhood), extending earlier work conducted at AAU and integrating the contributions of the CITY-STEP project.

PhD objectives

The PhD aims to overcome a first bottleneck: integrating fine-grained data from real walking on site with heterogeneous urban descriptors, some of which are of lower resolution, in order to relate pedestrian movement dynamics to urban morphology and urban atmospheres. A second bottleneck concerns scaling up, i.e., the ability to aggregate local and situated observations of pedestrian walking in the city into walkability indicators at the street and neighbourhood scales. The objectives are as follows:

- Contribute to the acquisition of in situ experimental data. The PhD includes an experimental component: the PhD candidate will participate in the design and implementation of data collection campaigns on site, in close interaction with the second PhD candidate in the CITY-STEP project led by GEOLOC, dedicated to developing walking models and producing and validating biomechanical indicators. This involvement will include, in particular, preparing study sites, defining routes, and documenting collection conditions.
- Structure and integrate the collected experimental data, including notably walking data from inertial sensors, eye-tracking data, urban and environmental data, pedestrians' perception feedback, as well as walking indicators produced within the other PhD of the project. Particular work will be dedicated to the spatial and temporal alignment of these heterogeneous data sources.
- Analyze relationships between the urban environment and walking dynamics, in collaboration with the project postdoctoral researcher, by identifying morphological, spatial, and sensory parameters (street configuration, discontinuities, atmospheres, vegetation, etc.) likely to influence pedestrian kinematics, with a specific focus on articulating fine-grained observations with urban description.
- Carry out the scaling-up between local observations from experimental field sites (step scale, instrumented segments) and broader representations of walkability (street and neighborhood scales), by proposing aggregation, generalization, and extrapolation methods for information derived from collected data in order to develop enriched walkability indicators. This work will build on prior AAU research on perception and urban indicators, while explicitly integrating information from real on-site walking produced and interpreted in collaboration with GEOLOC, with the aim of delivering indicators that are more sensitive to the viewpoint of pedestrians in motion. This work will notably rely on machine learning and deep learning methods, used for descriptor extraction, automatic annotation of urban environments, and generalization of results to larger scales.
- Assess the transferability and usability of these indicators, notably through exchanges and feedback with operational stakeholders, including the local authority partner, with the aim of supporting project owners in the design or improvement of pedestrian spaces.

Data to be used

The PhD will rely on a set of heterogeneous data, notably acquired in situ during the experimental campaigns of the CITY-STEP project. These data will include in particular:

- walking data from inertial sensors, to be exploited in the form of aggregated indicators that will be produced and interpreted in interaction with the GEOLOC-led PhD;
- eye-tracking data, enabling analysis of pedestrians' visual attention during walking;

- urban and morphological data describing the structure of the traversed space (street network, sidewalks, intersections, buildings, street furniture, vegetation), coming from national geographic reference datasets as well as open data and existing 2D/3D models;
- environmental and sensory data characterising urban atmospheres (lighting, noise, thermal conditions, presence of vegetation) to be extracted from videos recorded in the field;
- pedestrians' perception and experience feedback, collected at the end of the experimental routes.

Provisional work plan

Year 1
- Scientific and methodological familiarisation with the CITY-STEP project.
- Preparation of sites and experimental protocols.
- Participation in the first in situ experimental campaigns.
- Data structuring and first exploratory analyses.
- Production of initial scientific results.

Year 2
- Cross-analyses between urban morphology, perceptions, and walking dynamics.
- Formalisation of environment–walking relationships in connection with the GEOLOC PhD and the postdoctoral work.
- Continued scientific dissemination.

Year 3
- Scaling up and construction of multi-scale walkability indicators.
- Assessment of transferability with project partners.
- Scientific dissemination and PhD writing.

Supervision and scientific environment

The PhD will be carried out within the AAU-CRENAU laboratory (École Centrale de Nantes). It will be co-supervised by Myriam Servières, Thomas Leduc and Vincent Tourre, as well as Valérie Renaudin (GEOLOC laboratory, Université Gustave Eiffel).

Expected scientific outcomes

The PhD work is expected to lead to the following contributions:
- the formalization of methods enabling the integration of real on-site walking data into the analysis of urban walkability, in articulation with morphological and environmental descriptors;
- the proposal of enriched walkability indicators, sensitive to the viewpoint of pedestrians in motion and usable at the street and neighbourhood scales;
- an improved understanding of relationships between the urban environment, pedestrian perception, and walking dynamics, grounded in experimental data collected in situ.

These results will complement and extend prior work at AAU on perception and walkability indicators, while opening new methodological perspectives linked to the integration of real walking.

The PhD work will lead to scientific publications in international journals and conferences in the fields of urban research, spatial analysis, and data science. It will also contribute to the production of datasets and methods disseminated within an open science approach, consistent with the principles of the CITY-STEP project. Finally, the PhD will be embedded in the project's scientific outreach and dissemination activities (seminars, scientific events, exchanges with territorial stakeholders).

Expected profile

The candidate must hold a Master's degree or equivalent in computer science, geomatics, data science, or related disciplines. A strong interest in spatial analysis, urban environments, GIS, and complex data processing is expected. Knowledge in machine learning and deep learning is required, notably for the analysis of visual and multi-source data.

Skills in programming (Python), handling large datasets, and using deep learning libraries (e.g., PyTorch or TensorFlow) will be appreciated, as well as the ability to work in an interdisciplinary and collaborative framework.

References

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[9] Cao, Q., Tourre, V., Leduc, T., & Servières, M. (2026). Integrating functional accessibility and pedestrian environmental comfort: A spatially explicit framework for urban walkability evaluation. Environment and Planning B: Urban Analytics and City Science.