

From Car-Centric to People-Centric: Developing Street Transformations Through Environmental and Community Involvement Approaches

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Abstract

Car-centric urban planning has marginalised the social dimension of the streets and continues to cause various environmental and health issues. Cities have been developing strategies to address those challenges, transforming streets into public spaces that encourage active mobility. However, these efforts often lack participatory processes and heat mitigation strategies, both considered essential in such interventions. This paper proposes a methodology to address those issues, combining citizen science-based methods, such as thermal walks, and technical and administrative expertise. The four-phase participatory framework encompasses citizen engagement, data analysis, co-design of adaptation scenarios and their evaluation, combining the lived experience with the scientific knowledge and administrative considerations. The proposed approach provides inclusive and context-sensitive adaptation scenarios, enhancing both community acceptance and heat stress mitigation.

Keywords: Street transformation; Microclimate; Thermal comfort; Citizen science; Participation

1. Introduction

Most cities today are dependent on motorised transportation and the use of private cars. The role of the street has become predominantly to maximise transportation efficiency, disregarding its social dimension and placing people on the margins of public spaces (Ravazzoli and Torricelli 2017). The car-centric urban planning has caused various issues related to environmental pollution, energy consumption and inactive lifestyles (Nieuwenhuijsen and Khreis 2016; Mueller et al. 2020). To address these challenges, urban planning has recently prioritised a more sustainable, compact development characterised by higher density and diversity and shorter distances (Giles-Corti et al. 2016; Nieuwenhuijsen 2021). However, while this resulted in a decrease in CO₂ emissions and an increase in sustainable mobility opportunities, new issues arose from compact city planning that have detrimental impacts on human health. These include exposure to extreme heat, air and noise pollution, as well as a higher density of motorised traffic (Mueller et al. 2017; Khomenko et al. 2021; Nieuwenhuijsen 2021). In recent years, diverse strategies have increasingly been developed to respond to these problems, focusing on the redevelopment of streets and public spaces and promoting active mobility, in order to create more liveable, human-centred spaces. Reclaiming the spaces dedicated to motorised vehicles allows the transformation of the street function to an open public space that generates different aspects of urban life, affecting the quality of urban spaces, social interaction, physical activity, economic and environmental factors. These strategies vary from single street transformations to more complex urban models such as Superblocks in Barcelona or Low Traffic Neighbourhoods in London. They mainly involve the reduction of motorised traffic, a measure that often faces resistance from residents, making these strategies a controversial topic. Experiences from already implemented strategies strongly highlight the need for the inclusion of citizens in the development of such plans and interventions (Cruz and Paulino 2020; Lunetto et al. 2023; Vásquez et al. 2024). Participatory approaches enable integration of the needs and perspectives of the citizens in decision-making, leading to higher acceptance and usability of public spaces. Citizen engagement in the development of these interventions ensures their alignment with the community's requirements, while addressing the issues of urban development and climate change (Rodriguez and Komendantova 2022; Sondou et al. 2025).

On the other hand, these transformations could help mitigate the heat stress of pedestrians while promoting liveable streets and active mobility (Nieuwenhuijsen 2021). However, there is very limited evidence of thermal comfort considerations in such interventions, often considering the improvements in qualitative terms, without quantifying the actual impacts. This indicates a gap between the research on the issues of thermal comfort and heat mitigation and its implementation in urban planning.

Recognising the importance of the presented issues and their interconnections, this study focuses on the development of a methodology that integrates public participation and heat mitigation into street transformation processes aimed at promoting active mobility.

2. Methodology development

Due to the need to integrate participative processes and thermal comfort into street redesign plans, we propose a participatory framework that brings together citizens, experts and public administration. The framework adopts citizen science-based thermal walks, focusing on dynamic thermal comfort, to assess and measure thermal experience, with the aim of co-designing the adaptation scenarios. The process consists of four distinctive phases that follow after the need for intervention has been identified (Fig. 1).

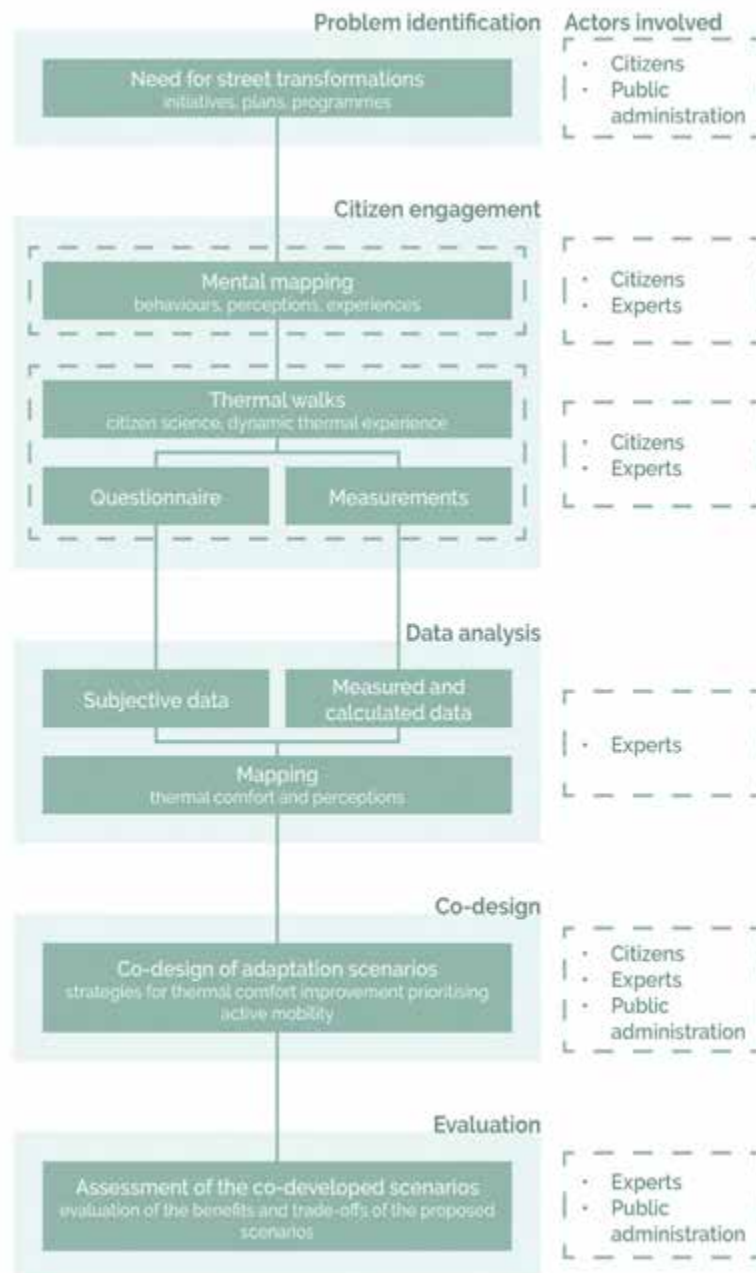


Figure 1. Phases of the proposed framework.

2.1 Citizen engagement

The phase of citizen engagement consists of two main activities – mental mapping and thermal walks. These activities have been used in the literature to examine both subjective thermal perceptions (Moderow et al. 2023; Květoňová et al. 2024) and to investigate dynamic thermal experiences (Vasilikou and Nikolopoulou 2020; Xie et al. 2022). Citizen engagement, especially thermal walks activities, is based on a citizen science approach. Citizen science has increasingly been utilised and studied as a method of empowerment, promoting behavioural change and collective action, while simultaneously increasing knowledge and awareness of the public and crowdsourcing data for research purposes (Sardo et al. 2024). This citizen science approach has been applied in various projects and studies, including microclimate research (Květoňová et al. 2024) and sustainable mobility (Sardo et al. 2024), highlighting the importance of citizen involvement in co-designing projects and policies. Incorporating citizen participation into street redesign processes could promote more inclusive, context-sensitive and scientifically informed urban planning practices.

2.1.1 Mental mapping

Mental or cognitive maps have been used to study people's perceptions of thermal comfort in urban environments, expanding the insights obtained using solely quantitative approaches. This qualitative method captures subjective experiences and behavioural adaptations, drawing on people's experiences to identify hotspots, cool areas, comfortable and uncomfortable spaces (Lenzholzer 2010; Lehnert et al. 2023; Moderow et al. 2023). As such, it serves as a valuable tool in participatory planning and climate adaptation, facilitating public engagement and co-creation (Foshag et al. 2020; Moderow et al. 2023). Cognitive maps emphasise the psychological and contextual aspects of thermal perception, which might differ from the objective data gathered through measurements or remote sensing (Květoňová et al. 2024). One limitation of this method is its tendency to focus on easily accessible or more frequented locations, potentially neglecting peripheral or less familiar areas (Květoňová et al. 2024). Nonetheless, this approach could be interpreted as a means of identifying locations with higher levels of public interest or activity, supporting prioritisation of possible intervention areas based on actual use rather than solely on objective data. Mental maps, combined with quantitative methods, could be instrumental in exploring differences between thermal expectations and thermal sensation and real thermal conditions, enhancing public participation in climate adaptation.

2.1.2 Thermal walks

Studies on microclimate conditions in urban areas often rely on static measurements and models to investigate thermal comfort (Ravnikar et al. 2023; Zhao et al. 2024). However, the static tools fail to account for diverse conditions experienced by humans while traversing urban spaces (Zhao et al. 2024). Dynamic thermal experience is based on different factors, including continuously changing environments (Lau et al. 2019; Zhao et al. 2024), psychological responses (Wang et al. 2022; Zhao et al. 2024), psychological responses (Vasilikou and Nikolopoulou 2020; Dzyuban et al. 2022; Jia et al. 2022; Mohite and Surawar 2024), thermal history and sequence of exposure (Nakayoshi et al. 2014; Xie et al. 2022; Zhao et al. 2024), alliesthesia (Dzyuban et al. 2022; Li et al. 2023; Zhao et al. 2024) and environmental variations (Lau et al. 2019; Lee et al. 2020; Dzyuban et al. 2022; Jia et al. 2022; Li et al. 2024; Mohite and Surawar 2024). To capture these different factors, recent studies have been using the thermal walks method, involving participants in assessing subjective perceptions along routes accompanied by mobile microclimate measuring devices, emphasising the importance of thermal perceptions and sensations for overall thermal comfort (Nakayoshi et al. 2014; Vasilikou and Nikolopoulou 2020; Dzyuban et al. 2022; Xie et al. 2022; Květoňová et al. 2024; Mohite and Surawar 2024). Studies employing thermal walks vary in their methodology, including the number of walks, instruments used and the duration of the study, based on their aims, type of study and availability of participants. Typically, thermal walks studies involve 10-15 participants (Vasilikou and Nikolopoulou 2020; Dzyuban et al. 2022; Květoňová et al. 2024; Mohite and Surawar 2024). Nevertheless, while some studies conduct only a single walk per participant (Dzyuban et al. 2022; Květoňová et al. 2024), others adopt a longitudinal approach with repeated walks across two seasons and multiple times of day (Vasilikou and Nikolopoulou 2020; Mohite and Surawar 2024). Most studies focused on the hottest period of the year, while longer ones considered both cold and warm weather. These methodological differences lead to significant variations in the amount of collected data, ranging from tens to hundreds of measurements and questionnaires.

Citizen science-oriented thermal walks, proposed in this study, have a twofold objective - to collect dynamic thermal experience data and to help raise citizens' awareness of the excessive heat issues and the potential of adaptation strategies, in terms of both the structural modifications, e.g. green infrastructure or changes in materials, and behavioural changes. The walks consist of two main activities, participatory microclimate measurements and a thermal perceptions questionnaire. During the walks, the citizens carry out the measurements using portable devices. Devices used in citizen science projects and experiments with similar aims are mainly low-cost mobile weather stations, measuring essential parameters such as air temperature and relative humidity (Kulkarni et al. 2022; Peña-Rodríguez et al. 2022; Hohenegger et al. 2023; Loglisci et al. 2024). These parameters mainly suffice the objectives of such studies, allowing the collection of the data needed for a better understanding of the weather conditions. However, to ensure the validity and precision of the collected data, additional measurements should be performed using professional equipment, e.g. a professional stationary weather station. The mobile measurements performed by the citizens allow real-time interpretation of the measured values and parameters, enhancing understanding and further raising their awareness of the heat-related issues in the urban areas.

The assessment of the people's perceptions is a fundamental component of the thermal walks. Subjective thermal experience is mainly examined through questionnaires and surveys based on the standards such as ISO 10551:2019 (International Organization for Standardization 2019) and ASHRAE Standard 55 (American Society of Heating 2023). The questionnaire includes personal data such as age, gender, weight, height and clothing information of the participants, in order to better understand the metabolic rates and clothing insulation, which are critical in thermal comfort investigations. To investigate the dynamic thermal experience, the questionnaire should include questions on thermal sensation, comfort and preference in different points of the walk, accounting for variations between different urban configurations and exposure (Vasilikou and Nikolopoulou 2020; Dzyuban et al. 2022; Xie et al. 2022; Mohite and Surawar 2024). Additionally, comparing instantaneous sensations at each point with the whole-trip experience would provide a more comprehensive understanding of the thermal experience during the walks (Zhao et al. 2024).

2.2 Data analysis

The analysis of the data collected through mental mapping and thermal walks follows different steps.

The data collected by the mobile measurement devices should be validated against that collected by the weather station on-site, to ensure their accuracy and reliability. Firstly, the raw sensor data needs to be pre-processed to remove statistical outliers before further analysis is performed (Schilt et al. 2023).

The methods commonly used for data validation between the measurement devices involve statistical validation methods and calibration techniques. Statistical metrics include Pearson and Spearman correlation coefficients, Mean Absolute Error (MAE), Root Mean Square Error (RMSE), sensor bias and regression analysis (Kureshi et al. 2022; Rivera et al. 2023; Schilt et al. 2023). Linear regression and machine learning methods are often used to calibrate low-cost sensors against reference data (Yamamoto et al. 2017; Kureshi et al. 2022).

Data collected from the thermal walks and the weather station could be used for the numerical simulation of thermal conditions. The simulations are often performed using computational fluid dynamics (CFD) software, e.g. ENVI-met, Ansys Fluent, or energy balance models (EBM), such as RayMan, SOLWEIG. These models mainly enable the spatial distribution of the weather parameters, including the calculation of thermal comfort indices such as Physiological Equivalent Temperature (PET), Universal Thermal Climate Index (UTCI) and others. Data obtained from the simulations should be further analysed and validated against the measurements. Methods commonly used for validating simulation performance are based on statistical approaches and metrics, e.g. RMSE, MAE, Mean Bias Error (MBE) (Peng et al. 2023; De Quadros et al. 2024).

Finally, the outputs of the questionnaire could be compared to the measured and simulated data to highlight possible differences between subjective perceptions and objective data. The data could be further analysed to evaluate different factors affecting the judgement of the participants. Scientific literature often employs

statistical analysis methods such as Spearman's correlation (Dzyuban et al. 2022), Pearson's correlation (Ma et al. 2021), path analysis (Chan et al. 2017; Peng et al. 2019; Ma et al. 2021) to understand the relationship between different variables.

The analysed data should be mapped to enable spatial visualisation of the data in different layers, facilitating the further steps of the process.

2.3 Co-design

Co-design is a collaborative approach that unites citizens, experts and public administration in the process of developing street transformation plans based on the knowledge and lived experience. This method gives voice to the community members, empowering them to shape innovative and contextually relevant outcomes and solutions (Echaniz et al. 2022). The importance of this approach is becoming increasingly recognised in urban interventions where the success depends on social acceptance and usability (Lunetto et al. 2023; Vásquez et al. 2024).

This phase involves all relevant stakeholders and community representatives to ensure inclusivity and integration of local values while taking into account technical knowledge and administrative considerations provided by experts and public authorities. The co-design workshops are based on the data and experience collected through citizen science experiments and mapping activities. The workshops are structured in four consecutive sections:

1. Presentation of findings and elaborated data from the previous activities and discussion, allowing all participants to share their personal experiences and insights.
2. Identification of priority areas and challenges for the interventions.
3. Conceptualisation of the possible scenarios and strategies addressing both heat-related issues and active mobility.
4. Refinement of the scenarios with the expert feedback and administrative constraints.

The outcome of the co-design phase is a set of street transformation scenarios that form the base for the evaluation and policy considerations in the following phase.

2.4 Evaluation

The evaluation phase is a crucial component aimed at critically assessing the co-designed adaptation scenarios from technical and socio-environmental perspectives. The scenarios are evaluated not only for thermal comfort improvements, but in a broader framework of benefits and trade-offs that include environmental, economic, social, health and mobility impacts, ensuring feasibility and effectiveness of the solutions. The multicriteria framework reflects the multifunctional nature of street spaces, highlighting the complexity of urban transformations. Due to the need to integrate the previously mentioned aspects and the stakeholder views and opinions, a multicriteria decision analysis (MCDA) approach is adopted. MCDA is a systematic methodology that combines different input factors with the considerations of stakeholders to compare and rank different project options (Huang et al. 2011).

The framework of different impacts is based on different indicators, depending on the types of strategies and interventions in the scenarios. Potential indicators and assessment methods are presented in Table 1.

Table 1. Framework of different impacts, potential indicators and assessment methods.

Impacts	Potential indicators
Environmental	Thermal comfort improvement Biodiversity benefits Air pollution reduction Noise pollution reduction
Economic	Cost of implementation Maintenance costs Impacts on property values Impacts on local businesses' activity
Social	Use of space Inclusivity Accessibility Safety
Health	Physical activity levels Mental health benefits Reduction in heat and air pollution exposure
Mobility	Changes in mobility flows and modes Changes in traffic speed and volume

3. Discussion

The participatory methodology developed in this study integrates thermal comfort considerations and participative processes into the development of street transformation plans. The four-phase framework is based on a holistic approach to urban adaptation, bridging the gap between scientific research, decision-making and local experience.

One of the strengths of this methodology is the combination of qualitative and quantitative approaches. Through citizen science-based thermal walks and participatory mapping, the process captures both subjective thermal experience and objective microclimate conditions. This approach helps translate and reflect the lived experience of the citizens in the design processes, fostering a bottom-up approach. The co-design phase involves citizens, experts and public authorities in the development of adaptation scenarios, enhancing the sense of ownership and legitimacy, essential for the acceptance and long-term success of the projects (Echaniz et al. 2022; Lunetto et al. 2023). The framework is further strengthened by adopting a multicriteria decision analysis approach to evaluate the co-developed scenarios. The comprehensive assessment encompassing environmental, economic, social, health and mobility dimensions, as well as stakeholders' perspectives, highlights various benefits and trade-offs of the solutions while supporting transparency in decision-making (Huang et al. 2011).

Despite its strengths, the methodology has several limitations. Firstly, the reliability of citizen-collected data can vary, especially when using low-cost devices. The framework addresses this issue through validation with professional equipment and calibration, however, the potential for error remains (Kureshi et al. 2022; Schilt et al. 2023). Secondly, a common challenge of participatory processes is ensuring inclusivity and broad participation. Citizen science activities primarily attract individuals already engaged in similar activities or with specific interests, potentially leading to underrepresentation of less vocal or marginalised groups (Květoňová et al. 2024).

The methodology provides opportunities for further research and practice in several ways. Longitudinal studies could use citizen-led thermal walks as a method to assess the impacts of the adaptation strategies after the implementation, enhancing and fostering participatory approaches long-term. Additionally, citizen engagement could be facilitated through the development or integration of digital tools, such as mapping platforms or apps for data collection, thereby enabling the accessibility of the data. Finally, the methodology could be tested across

different contexts, such as diverse climates or socio-economic environments, in comparative studies to help refine it and test its adaptability.

4. Conclusion

The contemporary street designs still prioritise motorised transport infrastructure, neglecting their potential as liveable public spaces. This study proposed a participatory methodology for integrating citizen engagement and thermal comfort considerations into street redesign processes aimed at promoting and encouraging active mobility, addressing the gap between research and its application in urban adaptation plans and strategies. By combining citizen science-based thermal walks, mental mapping, co-design and multicriteria evaluation, the framework unites technical and administrative expertise with lived experience, providing inclusive and context-sensitive adaptation scenarios.

The proposed approach addresses two significant gaps in current urban planning practice – the lack of thermal comfort considerations and the need for citizen participation in decision-making. By involving citizens directly in data collection and scenario development, the framework enhances the scientific basis of interventions while increasing public awareness, sense of ownership and acceptance. The methodology is further strengthened through multicriteria evaluation, assessing environmental, economic, social, health and mobility dimensions, accounting for benefits and trade-offs of each scenario.

While the methodology demonstrates significant potential for creating more liveable and people-centred open spaces, several limitations remain, mainly regarding the inclusivity of participatory processes and technical challenges of data analysis and evaluation. Future work will focus on testing and refining the methodology on a case study of Turin, within the Interreg Alpine Space project COMMONAIR.

Finally, this approach provides the foundation for more inclusive and adaptive urban street transformations. The framework fosters a replicable process that promotes rethinking of the streets as healthier and people-centred public spaces.

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