TeMA

Journal of Land Use, Mobility and Environment

print ISSN 1970-9889 e-ISSN 1970-9870
FedOA press - University of Naples Federico II

DOAJ
Rivista scientifica di classe A - 08/F1
Scopus
WEB OF SCIENCE

Special Issue 1.2026

Living and Walking in Cities

Mobility, Public Space and Spatial Justice

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TeMA

Journal of
Land Use, Mobility and Environment

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Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

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Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | online ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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TeMA

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Land Use, Mobility and Environment

TeMA Special Issue 1 (2026) 7-20
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/13112
Double-blind review under the responsibility of the "Living and Walking in Cities 2025" Conference Committee.

Walking access to public facilities in the touristic historic centre of Bologna: gaps and unbalances for residents and tourists

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Abstract

Promoting active mobility has become a critical challenge highly influenced by the quality of public spaces. The spatial distribution of urban destinations plays a relevant role in ameliorating the quality of the urban environment. Italian historic centres, in particular, are frequently touristic destinations where the attractiveness of pedestrians and the urban quality is relatively high. However, this high attractiveness especially for tourists and city users may undermine the possibility for residents to satisfy their needs due to the tourism impacts. Indeed, the rise in tourist numbers, driven by high-quality public spaces, accelerates touristification, reshaping the spatial layout and distribution of public facilities in historic centres. In this context, this study aims to evaluate the walking accessibility of public facilities to residents and tourists in historic centres, in order to highlight gaps and overconcentration of public facilities. Taking the historic centre of Bologna as a case study, this study uses ArcGIS geospatial analysis and the network analysis to calculate walking accessibility and spatial inequalities of public facilities from resident and tourist perspectives. The findings offer actionable recommendations for optimizing the use of public spaces and the land use layouts in Bologna and offer valuable insights for similar contexts.

Keywords

Active mobility; Historic centres; Accessibility; Public facilities; Residents and tourists

How to cite item in APA format

Chen, F. & Conticelli, E. (2025). Walking access to public facilities in the touristic historic centre of Bologna: gaps and unbalances for residents and tourists. *TeMA - Journal of Land Use, Mobility and Environment*, (1), 7-20. https://dx.doi.org/10.6093/1970-9870/13112

1. Introduction

Research on active mobility and sustainable has gained significant momentum in the field of urban design and planning, with a particular focus on the associations between public space and walking behaviour (Bianchi et al., 2023). The quality of public spaces directly reflects people's living experience. Therefore, the spatial distribution of urban destinations plays a relevant role in ameliorating the quality of the urban environment and is very important to promote spatial justice (Cai et al., 2022). Historic centres hold a unique place in urban environments, functioning as cultural, economic, and social hubs (Garau et al., 2023). The redevelopment of public spaces in historic centres encourages sustainable mobility, adds value to existent built heritage. Therefore. the encouragement of active mobility can be considered as a means of the quality and attractiveness of historic centres (Gargiulo & Sgambati, 2022). Italian historic centres are frequently touristic destinations where the attractiveness of pedestrians and the urban quality is relatively high (García-Hernández et al., 2017). However, the rise in tourist numbers, driven by high-quality public spaces, accelerates touristification (Gargiulo & Sgambati, 2022), reshaping the spatial layout and distribution of public facilities in historic centres, as residents and tourists have distinct facility needs (Huang et al., 2024). This shift alters the functional balance of historic centres, creating accessibility gaps and inequalities that impact both locals and visitors. Therefore, the walking accessibility of public facilities in historic centres should be evaluated to explore the conflicts between residents and tourists.

Existing literature on public facilities predominantly focuses on the spatial distribution and accessibility. In terms of the spatial distribution of public facilities, frequently studied types include public transport (Chen et al., 2023), supermarkets (Ren et al., 2022), and recreational facilities (Liu et al., 2022). Empirical evidence consistently reveals significant spatial disparities in the distribution of these public resources. Consequently, accessibility has been widely acknowledged as a crucial factor in regulating the spatial distribution of public facilities (Cai et al., 2022). Current research on public facility accessibility predominantly explores three key aspects: measurement methods, influencing factors, and facility types. A large number of studies have evaluated the accessibility of facilities such as green spaces (De Luca et al., 2021), schools (Sharma & Patil, 2024), and medical facilities (Xing et al., 2024). Common methods include network analysis (Li et al., 2025), the two-step floating catchment area (2SFCA) method (Yang et al., 2025), and gravity models (Liang et al., 2025). The existing research has primarily focused on the accessibility of public facilities in general urban spaces, with insufficient attention given to the spatial distribution of public facilities in historic centres (Giovannoni, 2022; Hsu et al., 2024). Moreover, as a tourist destination, historic centres have a diverse range of public facility needs from residents and tourists. This demand often results in spatial inequalities in facility utilization (Almeida-García et al., 2021). Therefore, addressing this spatial equity issue within historic centre has become a pressing concern. Another critical research gap lies in the lack of a comprehensive analysis that differentiates the facility needs of residents and tourists (Zheng & Zhao, 2023). Studies indicate that tourists and residents exhibit distinct needs for public facilities (Li et al., 2018). Tourists primarily seek cultural facilities, restaurants, and recreational spaces, while residents rely on stable public services such as public transportation facilities, medical services, and supermarkets (Huang et al., 2024). However, due to the process of tourism development, tourist-oriented public facilities have gradually taken a dominant role, leading to spatial disparities between resident-oriented and tourist-oriented public facilities (Li et al., 2018). This significant research gap limits the ability of urban planners to address the challenges posed by tourism, while also indirectly hindering the functional integrity of historic centres.

In this context, this study takes the historic centre of Bologna as the study area to evaluate the walking accessibility and spatial inequalities of public facilities under resident-oriented and tourist-oriented perspectives by using ArcGIS geospatial analysis and the Network Analyst. This study aims to evaluate the walking accessibility of public facilities to residents and tourists in historic centres, in order to highlight gaps and overconcentration of facilities and uses, to define possible strategies to reduce walking congestion and optimize the spatial layout of public facilities. Overall, this study makes some significant contributions. Methodologically, the spatial distribution of population and walking accessibility of public facilities in the historic centre were evaluated from both the perspectives of residents and tourists. From a practical perspective, a technical framework for the identification of conflict areas combining population and walking accessibility of public facilities in the historic centre of Bologna is constructed. Finally, the findings offer actionable recommendations for optimizing the use of public spaces and the land use layouts in Bologna and offer valuable insights for similar contexts.

2. Materials and methods

2.1 Study area

Bologna is a dense and compact city, at the heart of the Emilia-Romagna region of Italy (see Fig.1) (De Luca et al., 2024). According to the latest census data from 2021, Bologna is home to 394,843 residents, 52,325 of whom live within the historic centre (resource: https://populationstat.com/italy/bologna).

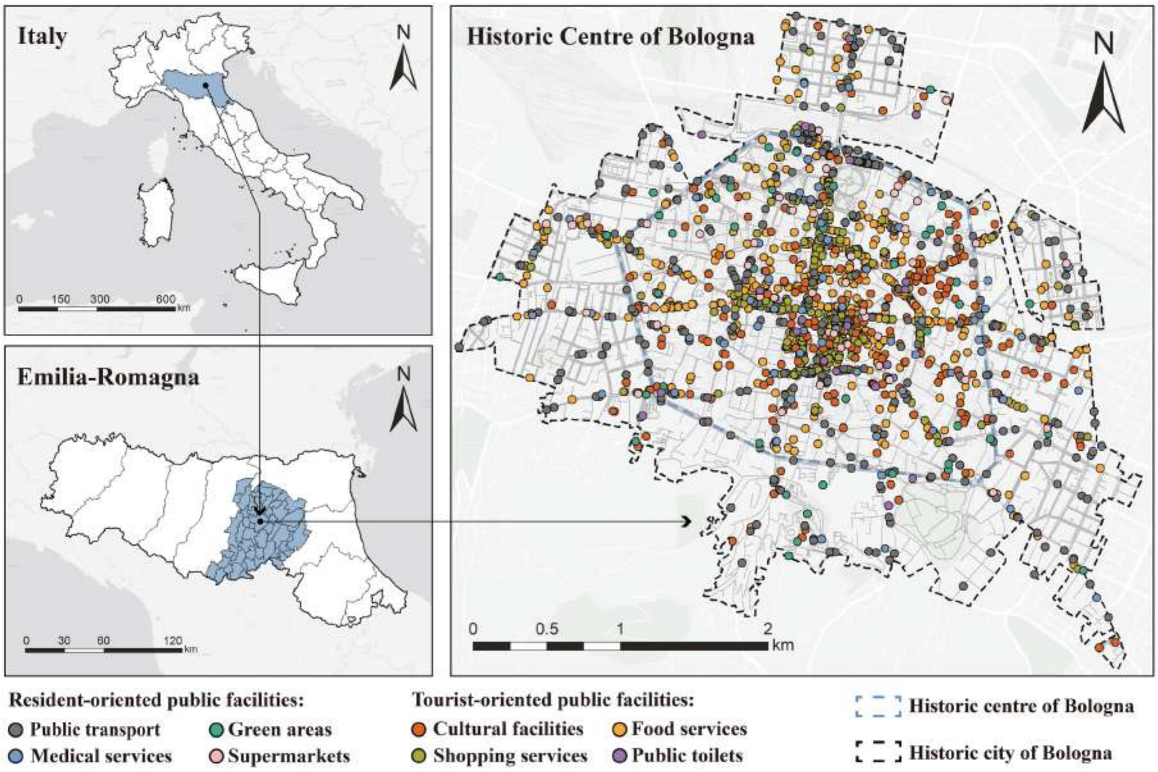


Fig.1 Location of the study area: Historic Centre of Bologna

Conventionally, historic centre of Bologna is considered to be the medieval area included in the ancient city walls built in the XIII Century, which coincides with the current ring avenues. However, this boundary was expanded by the 2008 Municipal Structural Plan, which introduced the "Historic City" concept. The 2021 General Urban Plan of Bologna further reinforced this concept, emphasizing integrated preservation of both the medieval core and its layered urban expansions (resource: https://whc.unesco.org/en/list/1650).

Historic centre of Bologna is particularly pedestrian-friendly, with a network of narrow streets flanked by porticoes, as well as numerous piazzas and squares and cultural heritage sites that are popular destinations for tourists (Gorrini et al., 2023). In 2024, Bologna received 4,098,212 tourist arrivals, which indicates an increase of 13.3% compared to the previous year. Therefore, the lack of infrastructure and the growing number of tourists have been exacerbating the conflict between tourists and residents.

2.2 Data collection

This study employs distribution data of public facilities, population and tourist data, and street network data. After completing basic data preprocessing tasks such as data cleaning, data spatialization, and spatial coordinate conversion, a database of walking accessibility to public facilities in historic centre of Bologna was established. All data were standardized to the WGS84 coordinate system in ArcGIS 10.8. The data range includes the historic centre of Bologna zone. In order to eliminate data errors in the marginal areas, the historic city of Bologna was established as a buffer zone (see Fig.1), which corresponds to the official historic city boundary established under the 2021 General Urban Plan of Bologna.

1) Distribution Data of Public Facilities

This study combined the online data of OpenStreetMap and Sitmaps of Bologna Government to collect the geographical distribution data of resident-oriented public facilities (public transportation facilities, green areas, medical services, and supermarkets) and tourist-oriented public facilities (cultural facilities, food services, shopping services, and public toilets) within the historic centre of Bologna.

2) Population Data

For residential population data, we used the geographic data of 2021 census sections provided by Istat to estimate the population numbers and distribution in the historic centre of Bologna (resource: https://www.istat.it/). For tourist population, Airbnb host points were used to estimate the population numbers and spatial distribution (resource: https://insideairbnb.com/bologna/). A total of 681 census area centroids and 3,119 Airbnb host points were collected.

3) Street Network Data

The street network data set was obtained from OpenStreetMap. First, all pedestrian street segments were screened. Then the field geometry calculator was used to calculate the distance in ArcGIS 10.8. Finally, the walking time of each street segment was calculated based on the walking speed. Considering that walking speeds vary across population groups, the distance covered may differ accordingly. For instance, older adults typically walk at around 3.5 km/h, while most studies use an average walking speed of 5 km/h (Schimpl et al., 2011). However, since the aim of this study is to identify conflict areas between tourists and residents, a standardized average speed was set to 5 km/h.

2.3 Data calculation

In order to evaluate the walking accessibility of public facilities and to identify the conflict areas in the use of public facilities, the following analysis is required. The analysis workflow is shown in Fig.2.

Phase 1) spatial distribution of population

Kriging Interpolation Method

In this study, in order to obtain the spatial distribution of resident population and tourist population, the Kriging interpolation method was used. Population data were used as input, with resident population interpolated from census area centroids and tourist population from Airbnb host points. This method utilizes ArcGIS 10.8 software to fit a variation function that determines the trend of regionalization variables, estimating the population value through interpolation (Sun et al., 2023). The purpose of using Kriging is to redistribute population data across a continuous surface, allowing population values to be estimated at a finer spatial scale than the original units. The Kriging formula is shown in Eq. (1):

$$Z(\mu) = \sum_{\alpha=1}^{n} \lambda_{\alpha}(\mu)\, Z(\mu_{\alpha}) \quad (1)$$

where $Z(\mu)$ is the predicted population value at location μ, $Z(\mu_{\alpha})$ are known population values, and $\lambda_{\alpha}(\mu)$ are weights based on spatial relationships (Shad et al., 2009). Based on the interpolation results, a raster surface was generated to represent the continuous population distribution. This raster was further integrated into a 50m×50m grid system, where each grid cell corresponds to a predicted population value.

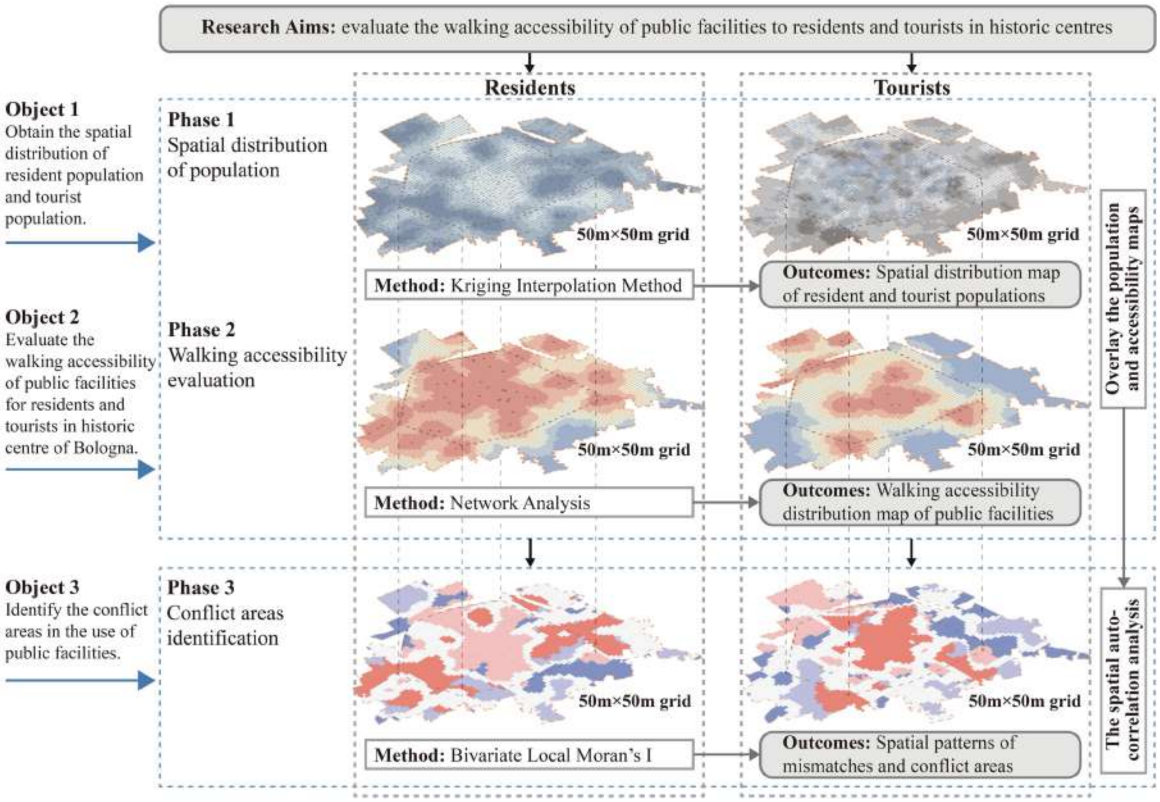


Fig.2 The analysis workflow

Phase 2) walking accessibility evaluation

Network Analysis

Walking accessibility to public facilities has been calculated through Network Analysis in ArcGIS 10.8 software (Li et al., 2025). To achieve this goal, we needed to use the distribution data of public facilities and street network data. Based on the Isochrone Analysis in Network Analysis, the isochrone ranges of the walking accessibility were obtained. The algorithm calculates travel time along the road network, until the travel time exceeds the given limits (Pedigo & Odoi, 2010). The time periods for this study are set to 0-2min, 2-4min, 4-6min, 6-8min, 8-10min, and >10min. Finally, the same as the processing steps of population data, the accessibility data was generated into the raster datasets, and a 50m×50m grid framework is constructed. The raster data is integrated into the grid system through spatial overlay analysis. Each grid will correspond to a specific accessibility value.

Phase 3) Identification of the conflict areas

Bivariate Local Moran's I

In this study, conflict areas refer to areas within the historic centre where accessibility does not match the population of residents and tourists. Such mismatches may indicate high demand population is not met with adequate service provision, resulting in an imbalance between accessibility and population. Bivariate local Moran's I (bi-LISA) is used to identify the spatial patterns of mismatches between accessibility and population in historic centre of Bologna, and to identify the conflict areas in the use of public facilities (Liang et al., 2023). The formula of bi-LISA is shown as Eq. (2):

where Z_x^a is the accessibility value of public facilities in grid a, Z_y^b is the number of residents or tourists in grid

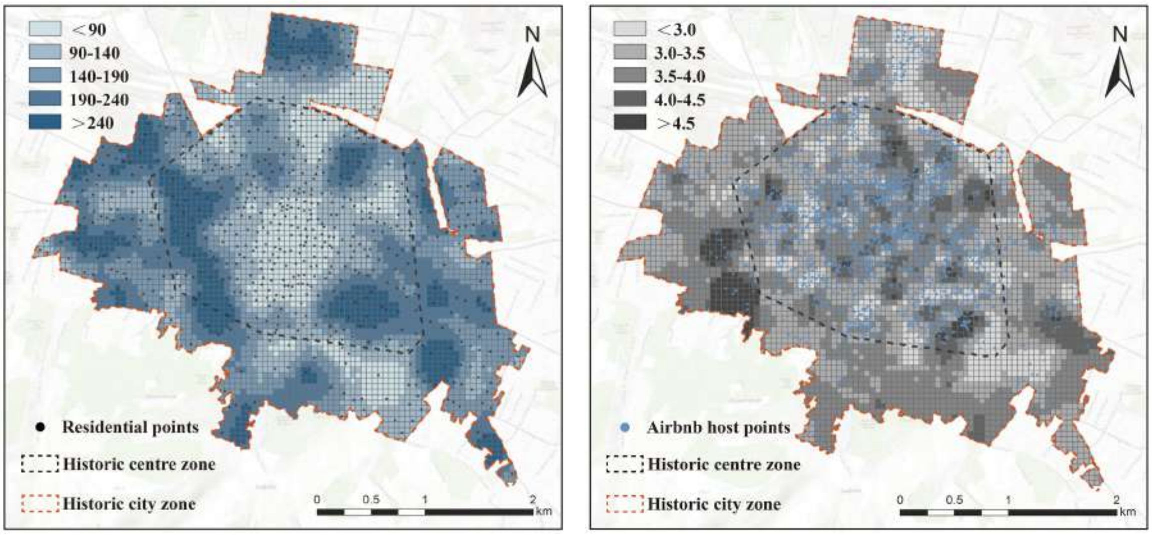
$$I_{xy}^a = Z_x^a \sum_j W_{ab} Z_y^b \quad (2)$$

b, and W_{ab} is the spatial weight matrix that represents the spatial relationship between grid a and its neighboring grid b, which equals 1 when a and b share a border. bi-LISA identifies four types of spatial clustering of accessibility and population: high-high, high-low, low-high, and low-low (Yang et al., 2025). High-high and low-low represent high- and low-value clusters of accessibility and population, respectively. High-low represents the spatial mismatch between higher accessibility and lower population, and low-high is the opposite.

3. Results

3.1 Spatial distribution of the resident and tourist population

We obtained the spatial distribution of the resident population and the tourist population within the historic city of Bologna. The spatial distribution map of the resident population is shown in Fig.3a and represent the population density in a 50mx50m grid cell. The resident population density exhibits a distinct radial increase from some core areas toward peripheral zones. High-density clusters (>240 individuals/grid) predominantly occupy western (San Felice), northern (Bolognina), and southeastern (Santo Stefano) neighbourhoods. Moderately populated areas (90-240 individuals/grid) establish an anular transition belt encircling the historic centre, while the core area demonstrate markedly reduced residential densities (<90 individuals/grid) near the most relevant historic buildings and public spaces.



(a) (b)

Fig.3 (a) The spatial distribution map of resident population; (b) The spatial distribution map of tourist population

The spatial distribution map of the tourist population is shown in Fig.3b. Areas with a high density of the tourist population (>4.5 individuals/grid) are mainly concentrated in the historic centre of Bologna, particularly near Central Station, Porta Santo Stefano, Porta San Donato, and Piazza Minghetti. In the outer area of the historic centre, two "anomalous" hot spots emerges at Porta Saragozza (>10 visitors/km^2), attributable to two high-capacity Airbnb points: Villa Bottrigari and Saragozza Apartment. The tourist population in the remaining outer areas is less than 3.5 people/grid, highlighting the spatially bounded nature of tourism activity. Furthermore, it is notable that approximately 81% of Airbnb host points are concentrated within the historic centre, intensifying competition with residents and contributing to displacing resident-oriented services.

The spatial distribution of populations reveals contrasting patterns between residents and tourists. While the historic centre still hosts a notable number of residents, its resident population is smaller than that of the surrounding areas, contrasting with tourist population trend, more concentrated in the core areas.

3.2 Accessibility of public facilities for residents

The spatial distribution of the walking accessibility to resident-oriented public facilities is shown in Fig.4. There are 347 public transportation stops, 46 green areas, 69 medical services, and 43 supermarkets. Public transport facilities, medical services, and supermarkets are concentrated in the core area, while green spaces are mainly concentrated in the fringe areas of the historic centre.

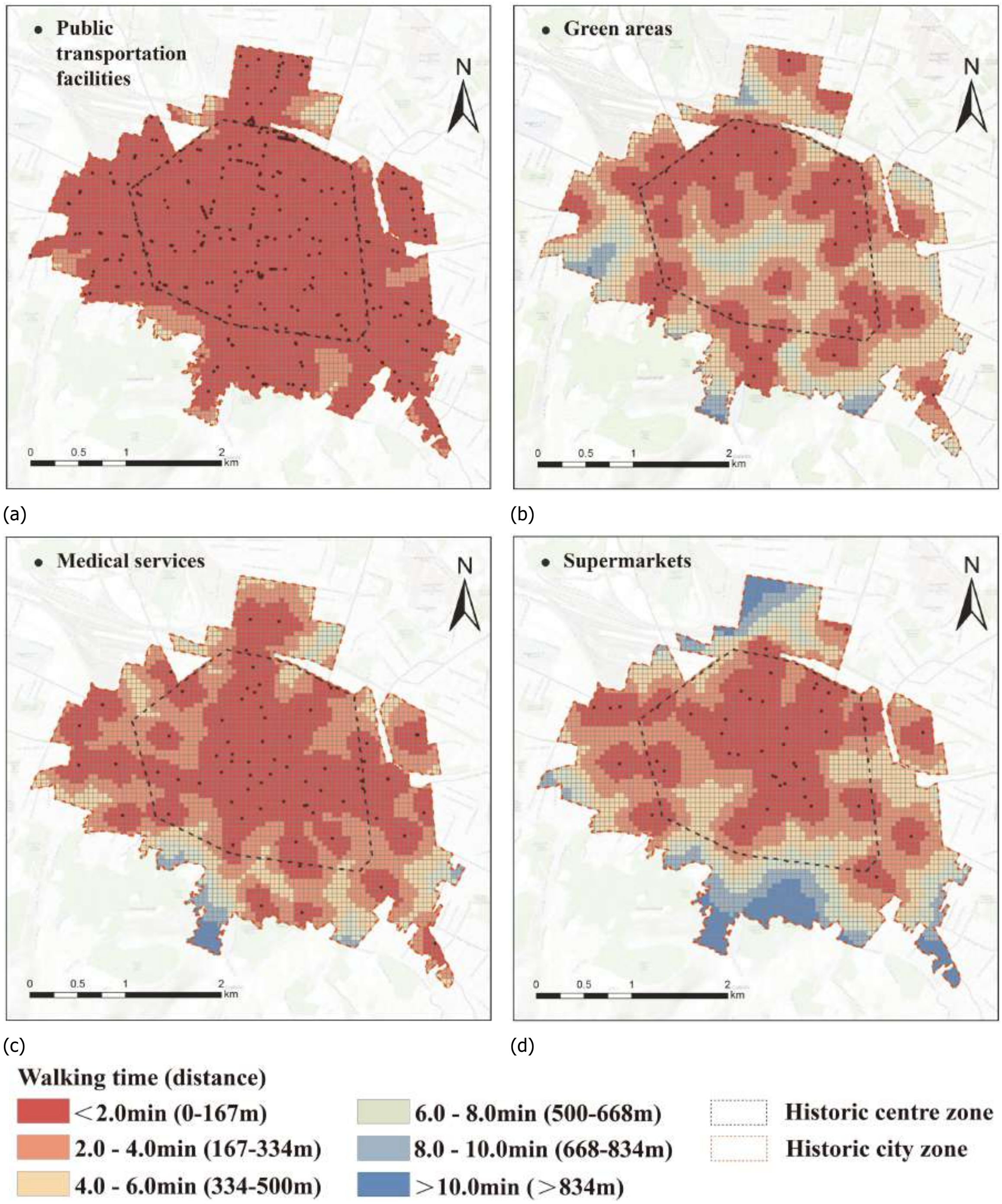


Fig.4 (a) Walking accessibility of public transportation facilities; (b) Walking accessibility of green areas; (c) Walking accessibility of medical services ; (d) Walking accessibility of supermarkets

Walking accessibility to public transportation facilities is highest throughout the study area. All public transportation facilities can be reached within an 8-minute walk. Within the boundaries of the historic centre, the majority of areas are able to get medical services and supermarkets within a 6-minute walk. Green areas, on the other hand, perform poorly in terms of walking accessibility, showing a trend of high accessibility in the fringe areas and low accessibility to the core. Green areas in the historic centre can be reached within an 8-minute walk and the size of the green spaces is generally very small.

However, considering that the population is not evenly distributed, it is necessary to introduce the resident population distribution to further measure the walking accessibility. Therefore, this study evaluated the percentage of population and territory area covered for different walking times, as shown in Fig.5.

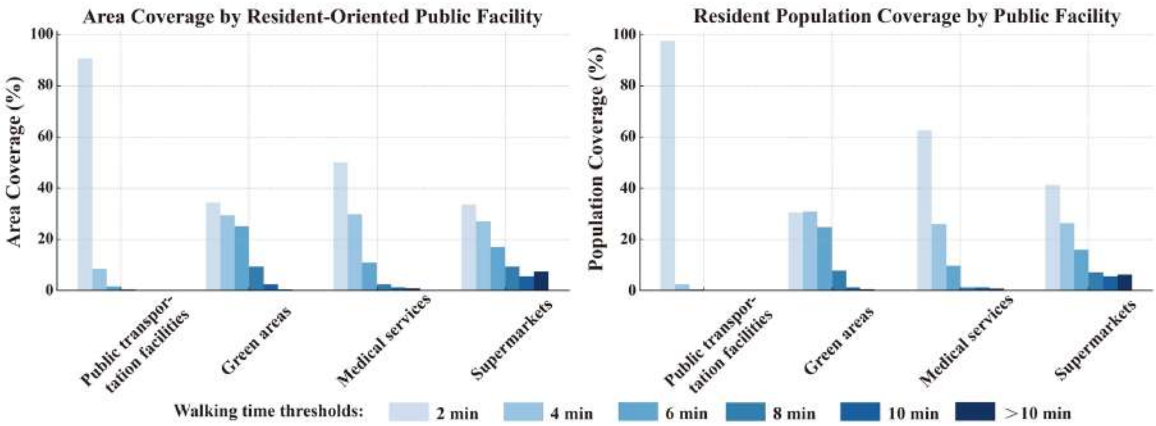


Fig.5 The resident population and territorial area covered by public facilities

Public transportation facilities exhibit a highly centralized pattern, with 90.95% of the area and 97.32% of the population covered within a 2-minute walking distance. By 6 minutes, coverage extends to 99.98% of the area and 100% of the population, indicating that the entire study area has been basically covered. Green areas follow a more gradual spatial distribution, with 33.97% of the area and 31.56% of the population accessible within 2 minutes, expanding to 62.81% and 65.58% at 4 minutes, and covering nearly all residents by 10 minutes. Medical services are accessible to 50.05% of the area and 62.04% of the population within 2 minutes, increasing to 81.81% and 87.49% at 4 minutes, and reaching nearly complete coverage at 10 minutes. Different from the first three infrastructures, supermarkets are accessible to 34.17% of the area and 41.75% of the population within 2 minutes, expanding to 60.6% and 67.53% at 4 minutes. However, 5.79% of the population is still not covered within a 10-minute walking distance.

3.3 Accessibility of public facilities for tourists

The spatial distribution of the walking accessibility to tourist-oriented public facilities is shown in Fig.6. There are 219 cultural facilities, 519 food services, 292 shopping services, and 19 public toilets in the study area. Cultural facilities are more numerous yet exhibit a widely dispersed spatial distribution, whereas food and shopping services are highly concentrated within the core of the historic centre. In contrast, public toilets are limited in number and display an exceptionally scattered distribution pattern.

Walking accessibility to cultural facilities is highest. Most cultural facilities can be reached within a 10-minute walk. Within the boundaries of the historic centre, the majority of areas are able to get food services and shopping services within a 6-minute walk. Public toilets exhibit the lowest level of walking accessibility, with the majority requiring more than 6 minutes of walking to reach. Similar to the resident-oriented analysis, incorporating tourist population distribution is essential for a more comprehensive assessment of walking accessibility (see Fig.7).

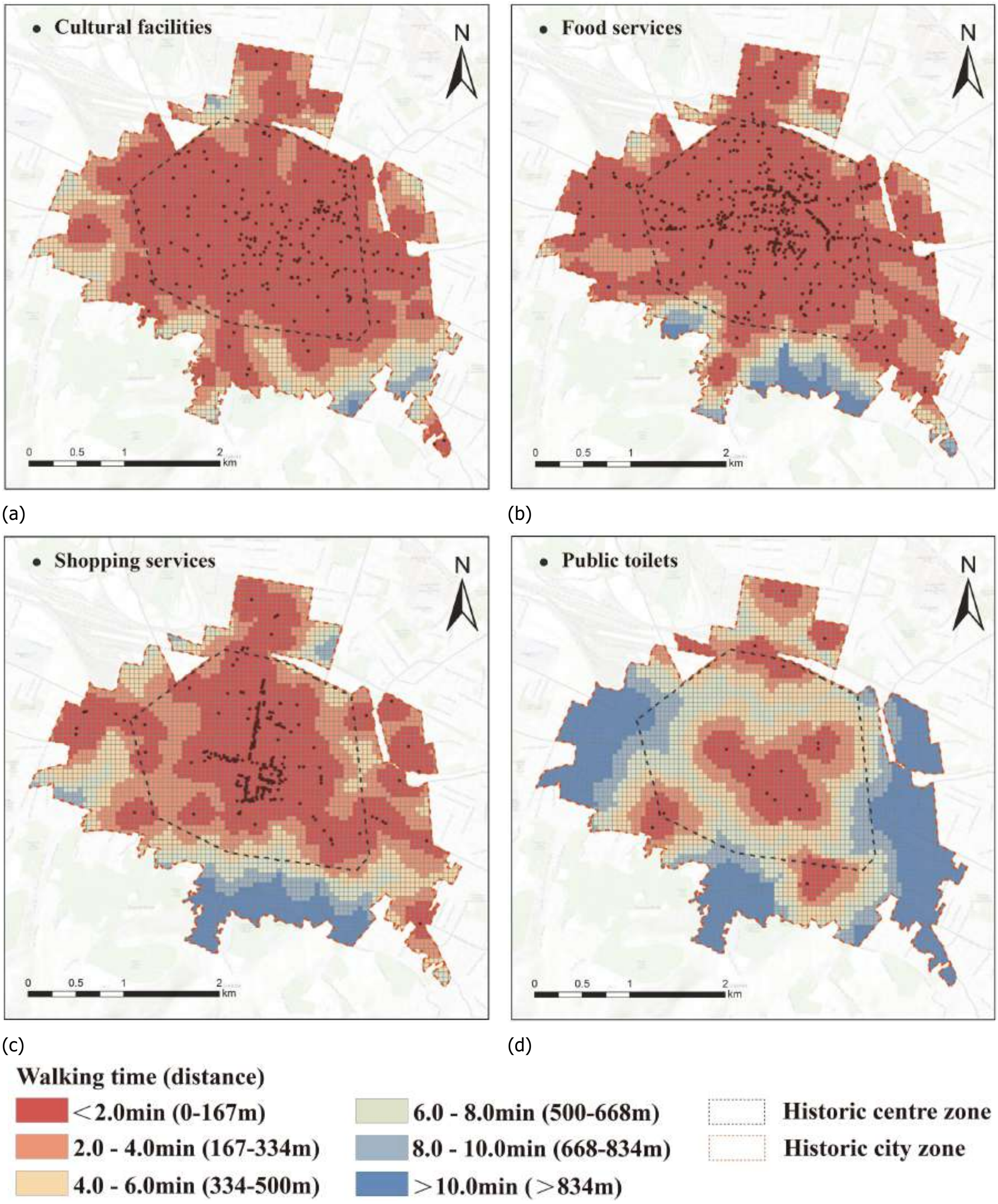


Fig.6 (a) Walking accessibility of cultural facilities; (b) Walking accessibility of food services; (c) Walking accessibility of shopping services ; (d) Walking accessibility of public toilets

Food services are the most highly concentrated facilities, with 76.98% of the area and 96.54% of the tourist population covered within a 2-minute walking distance. By 6 minutes, coverage extends to 94.27% of the area and 99.47% of the population. Cultural facilities are accessible to 65.13% of the area and 86.68% of the tourist population within 2 minutes, increasing to 83.52% and 96.01% at 4 minutes, and reaching nearly complete coverage at 8 minutes. Although shopping services are concentrated, they are distributed linearly in space, with 45.03% of the area and 72.26% of the tourist population accessible within 2 minutes, expanding to 70.75% and 92.71% at 4 minutes, and covering nearly all tourists by 10 minutes. Public toilets exhibit a distinct accessibility pattern, with 27.04% of the tourist population remaining beyond a 10-minute walking distance, indicating significant gaps in coverage.

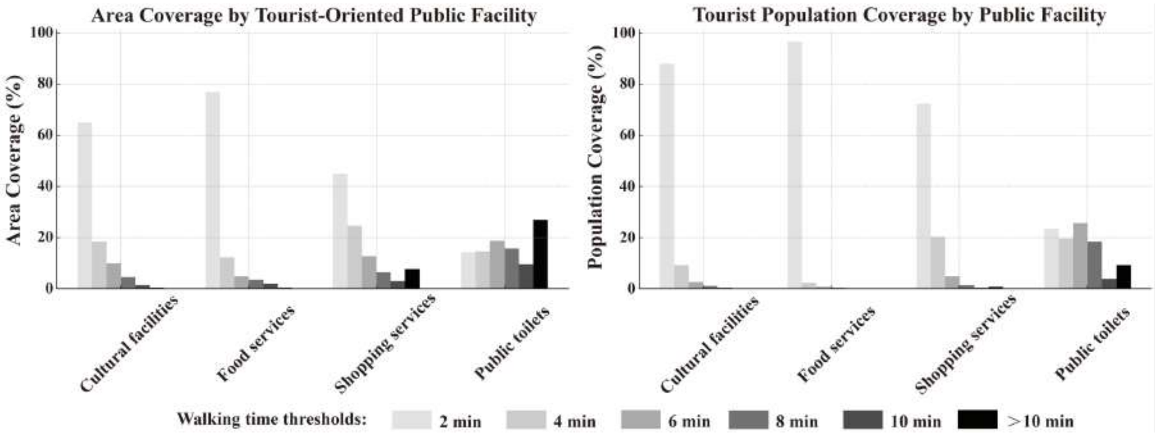


Fig.7 The tourist population and territorial area covered by public facilities

3.4 Conflict areas identification

The bi-LISA analysis reveals the conflict areas between accessibility and the resident population in historic centre of Bologna (see Fig.8). The results show a significant spatial autocorrelation between accessibility and the resident population.

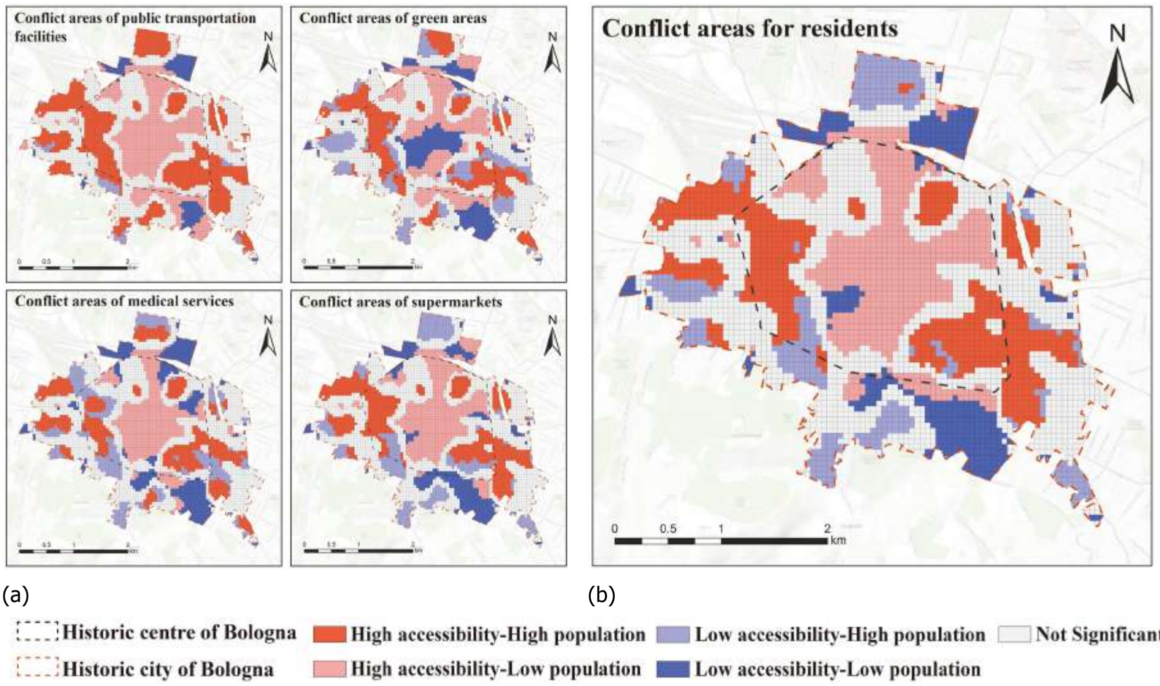


Fig.8 (a) Conflict areas identification of different facilities; (b) Conflict areas identification for residents

For public transportation facilities, areas with high accessibility and low population (High-Low clusters) are mainly concentrated in the core of the historic centre, whereas areas with high accessibility and high population (Low-High clusters) are predominantly located on the periphery or in outer areas. In the case of green areas, the core of the historic centre exhibits low accessibility and low population (Low-Low clusters), while the spatial distribution of other areas largely aligns with that of public transportation facilities. Medical services and supermarkets follow a similar spatial mismatch pattern, where High-Low clusters are mainly found in the core areas, whereas Low-High clusters are primarily located in its fringe areas or outer areas. Fig.8b illustrates the overall mismatch pattern between the total walking accessibility of the four types of public facilities and the resident population. High-High clusters are mainly concentrated on the periphery of the historic centre, High-

Low clusters dominate the core area, while Low-High and Low-Low clusters are primarily located in the outer areas.

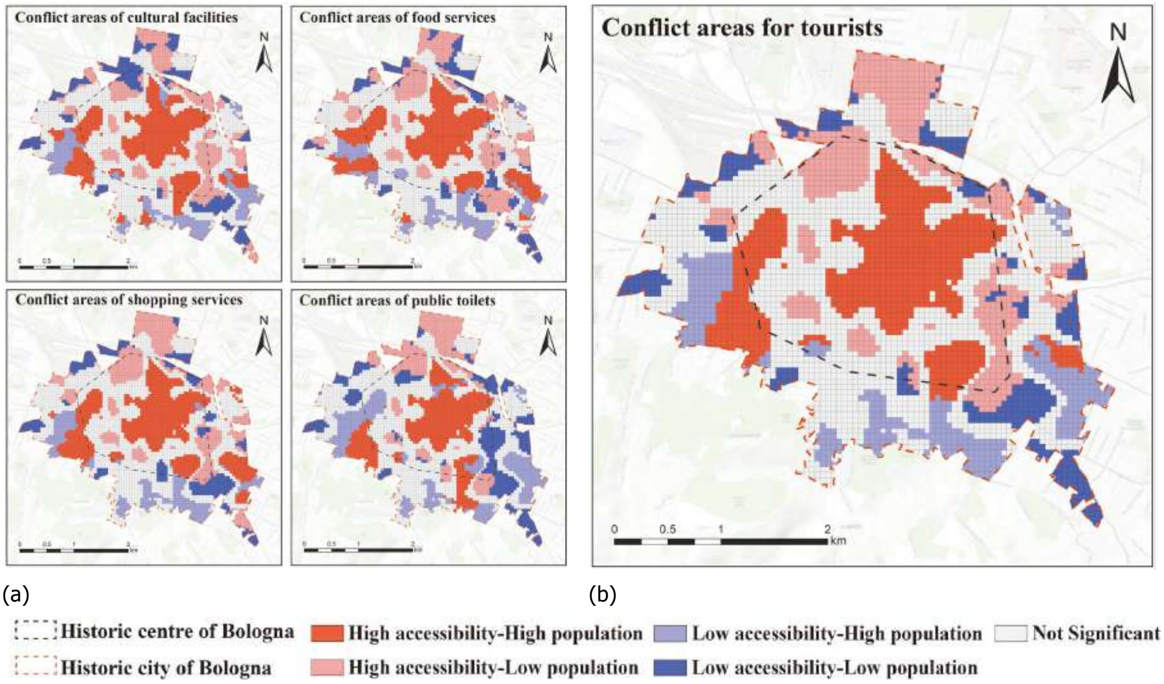


Fig.9 (a) Conflict areas identification of different facilities; (b) Conflict areas identification for tourists

The conflict areas identification between accessibility and the tourist population is shown in Fig.9. Unlike resident-oriented facilities, High-Low clusters for four facility types cover a smaller area and are mainly concentrated on the periphery or in outer areas. High-High clusters are primarily located in the core area, while Low-High and Low-Low clusters are concentrated in the outer areas. The spatial mismatch patterns of cultural facilities, food services, and shopping facilities are similar, whereas public toilets exhibit a greater proportion of Low-High and Low-Low clusters, predominantly found in the fringe areas or outer areas. Fig.9b presents the overall mismatch pattern between the total accessibility of the four public facility types and the tourist population. High-High clusters are mainly concentrated in the core area, High-Low clusters are found on its periphery, while Low-High and Low-Low clusters are primarily distributed in the outer areas.

4. Discussion and conclusions

This study evaluated the walking accessibility of public facilities under resident-oriented and tourist-oriented perspectives. The results revealed that significant variations in the spatial distribution and walking accessibility of resident-oriented and tourist-oriented public facilities. As for walking accessibility for residents, public transportation facilities and medical services are highly accessible, meeting most residents' needs. However, supermarkets have limited accessibility, with some residents needing to walk over 10 minutes for basic shopping. Green areas have the lowest accessibility, requiring long walking distances for core-area residents, restricting daily activities. For tourists, cultural facilities, food services, and shopping services are highly accessible, but public toilets have extremely poor accessibility, with 27.04% of tourists needing to walk over 10 minutes, significantly impacting their experience. This pattern of walking accessibility is also consistent with the results of some studies (Zheng & Zhao, 2023).

After further integrating the walking accessibility with population demand, the High-Low clusters reveals the conflict areas between accessibility and the population. Based on the clusters, we can explore potential optimization strategies for the spatial distribution of public facilities (Wolff, 2021). High-High clusters indicate possible facility overcrowding and service strain, requiring deepened analysis to understand the carrying capacity and increased maintenance to prevent resource shortages. In contrast, High-Low clusters suggest possible underutilized resources and potential service surplus, calling for eventual redistribution of flows and presences and strategic resource redistribution. Low-High clusters highlight unmet population needs and spatial inequality, necessitating facility optimization to improve coverage. Meanwhile, Low-Low clusters indicate potential future demand and vulnerability, requiring selective improvements based on evolving needs (Liang et al., 2023). Among these, Low-High clusters represent the most relevant supply-demand mismatch and require close attention (Yang et al., 2025).

However, this study has certain limitations. There are more possibilities in the selection of public facilities, and the shared use of facilities by residents and tourists could be considered in future research (Tang et al., 2024). As for the accessibility measurement methods, future studies could incorporate factors such as time thresholds for different facilities or users and facility capacity thresholds describing the optimal use of the different facilities, to provide a more comprehensive perspective (Liang et al., 2025). Most importantly, this study overlooks these temporal variations (He & He, 2025). For example, changes across different days, weeks, as well as the seasonality of tourist activities. This limitation arises primarily due to constraints in data availability and collection.

Overall, this study evaluated the walking accessibility of public facilities in the historic centre from both resident and tourist perspectives, revealing facility distribution gaps and imbalances in usage. Additionally, it constructed a technical framework for the identification of conflict areas combining population and walking accessibility of public facilities in the historic centre of Bologna. The findings provides practical recommendations for optimizing the use of public spaces and the land use layouts in Bologna and offer valuable insights for similar contexts.

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