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ENHANCING URBAN VITALITY: NEIGHBOURHOOD-SCALE ASSESSMENTS AND IMPLEMENTATION STRATEGIES

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Abstract: The growing interest in assessing urban vitality stems from the availability of various data sources, such as social media and geographic data. However, while existing literature predominantly focuses on assessing urban vitality, there remains a dearth of studies addressing its practical implementation. To address this gap, this study employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guideline to conduct a systematic review of articles from 2014 to 2024, sourced from Web of Science and Scopus. It utilises a multidimensional assessment at the neighbourhood scale, demonstrating how design and urban management can influence vitality. Focusing on Dongting Street in Wuxi City, China, this study then analyses location-based service data and heat maps to reveal vitality variations across locales and times. The findings highlight the importance of diverse facilities in promoting pedestrian activity and enhancing street-level vitality. By bridging theoretical understanding with practical applications, this research offers a structured approach to guide urban planners, designers, and policymakers in implementing neighbourhood-scale vitality strategies. It also outlines future research directions such as improving vitality measurements for marginalised groups and examining the interplay of multiple indicators in shaping urban vitality.

Keywords: Urban vitality, neighbourhood scale, implementation, PRISMA method.

Introduction

Exploring the relationship between human activity and urban space has always been an important topic in the field of urban research, with vitality serving as a key element in the relationship (Lynch, 1984). Vitality reflects human activity across various locations and times, acting as a fundamental dynamic within the city and an important indicator of liveability (Lynch, 1964; Landry, 2000). It is imperative to understand urban vitality to not only enhance the quality of life, but also to ensure the sustainable growth of cities (Lang *et al*., 2016). Vitality is initially observed at the urban level in geographical studies. Since 2005, the assessment of vitality has broadened its scope from the level of cities to the neighbourhood scale.

The advent of geographic big data has led to a gradual growth in research on vitality assessments. The current literature focuses on three levels of optimisation in assessment strategies using new data and Artificial Intelligence (AI) approaches: Regional, city, and neighbourhood. At the regional level, these studies have examined the trends of expansion and reduction in the geographical and economic strength of metropolitan regions (Lang *et al*., 2020; Huang *et al*., 2021). The integration of more data-based vitality assessments at the city scale is becoming more prevalent and the evaluation dimensions are more diverse (Wu *et al*., 2018; Li *et al*., 2022).

At the neighbourhood level, urban life is often demonstrated by urban activities and interactions with small-scale spatial entities (Yue *et al*., 2017) and grouped them into four categories: The neighbourhood, the streets, parks, and metro station regions within it. Techniques for evaluating vitality at this level are also evolving, resulting in in-time empirical data. Since 2008, research has used remotely sensed imagery to measure neighbourhood vitality (Barrios Jr, 2008). In recent years, streetscape data employing monitoring techniques and merging machine learning have appeared (Qi *et al*., 2020; Li *et al*., 2021).

However, while these advancements have improved measurement techniques, the literature still lacks a systematic analysis of how such vitality assessments inform urban planning, design, and policy interventions. At the city level, the existing literature explores practical policy and management issues for enhancing urban vitality such as the managerial implications of coordinating planning policies with design concepts to optimise resource allocation for sustainable development (Li *et al*., 2022).

Studies also offer guidance on the built environment in micro-spaces at the neighbourhood scale. For example, authorities in Portland, Oregon in the United States have issued recommendations to protect vendors and street activities from excessive regulation following an evaluation of the influence of street cuisine on the city's community life (Newman & Burnett, 2013). Similarly, recommendations have been made to plan smaller parks with improved water quality, fitness, and sanitation facilities to enhance visitor experience and service efficiency (Mu *et al*., 2021).

However, there has not been a comprehensive review of how urban vitality assessments are conducted and implemented. Several academics have investigated urban vitality evaluations in terms of indicators, influencing variables, and their links with urban design and urbanisation (Song *et al*., 2020), there has not been a scoping review or outlook on how to align urban vitality research more effectively with policy, planning, and design practices. Therefore, despite the emergence of implementation-focused urban vitality assessments in recent years, there remains an urgent need for relevant scoping reviews.

Furthermore, the relatively large regional and urban scale is not directly related to vitality enhancement implementation. In contrast, neighbourhood-scale spaces serve as the fundamental unit for vitality enhancement, with most regeneration projects focusing on this scale (Sharifi & Murayama, 2013). Therefore, the neighbourhood scale, comprising small-scale areas at the daily intervention level and offering manageable starting points for vitality enhancement was selected for evaluation based on the implementation-oriented efficacy of this study.

This study aims to address the current research gap by scrutinising the methodology and content of urban vitality evaluation, with the goal of enhancing its applicability to the realms of planning, design, and policy. By doing so, it seeks to facilitate more effective implementation of insights derived from neighbourhood-scale vitality studies in practical contexts and policy formulation. Additionally, this research delves into the methodology and content of urban vitality evaluation to heighten its pertinence to the domains of planning, design, and policy. Furthermore, the study endeavours to contribute to the effective implementation of neighbourhood-scale vitality research by identifying relationships and gaps between vitality assessment and enhancement implementation. Utilising case studies, it evaluates whether the research methodology and subject matter can effectively address these disparities.

Methods

This study comprised two phases. In the first phase, a systematic literature review of pertinent articles from the Web of Science and Scopus databases spanning from 2014 to 2024 was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. This review aimed to summarise a multidimensional assessment of vitality at the community scale while identifying gaps between research and practice.

Additionally, a bibliometric analysis was conducted using VOSviewer to visualise the co-occurrence of keywords and research trends within the selected literature. In the second phase, a case study was employed, focusing on a specific neighbourhood known as Dongting

Street in Xishan district, Wuxi, a southern city in Jiangsu province, China. The evaluation of neighbourhood vitality utilised Point of Interest (POI) and heat map data, with emphasis on exploring implementation strategies.

This systematic review adhered to the PRISMA protocol for guideline development and systematic review construction The PRISMA methodology, known for its systematic literature review approach was utilised for literature screening (Liberati *et al*., 2009).

To summarise and sort out the neighbourhood-scale vitality assessment in the identification phase, two databases (Web of Science and Scopus) were searched for articles using a search string created with Boolean operations ("urban vitality" OR "street vitality" OR "neighbourhood vitality" OR "city vitality" OR "space vitality" OR "urban vibrancy" OR "street vibrancy" OR "neighbourhood vibrancy" OR "city vibrancy" OR "space vibrancy") AND ("design" OR "planning" OR "policy" OR "management"). The search was limited to English-language studies published between 2014 and 2024. After the literature search, the screening and eligibility review was carried out. Articles included in this review had to fulfil the inclusion and exclusion criteria listed in Table 1. The final number of valid empirical research literature was determined to be 36 and the process is shown in Figure 1. All searched articles were retrieved and uploaded to the Mendeley tool for a systematic review. For data extraction, all articles were assessed in four areas using a standardised template: Study context, data collection methods, influencing factors and results.

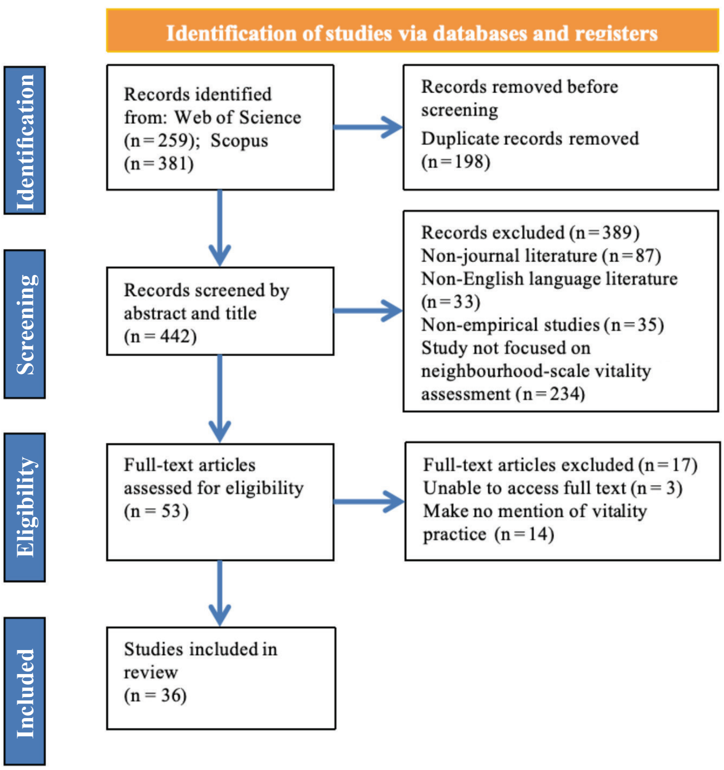

Figure 1: PRISMA flow diagram for article selection

Table 1: Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
(1) Studies of English writing (2) Publish time: 2014-2024 (3) Scholarly papers (4) Empirical studies (5) Papers that studied vitality assessment at neighbourhood scale (6) Papers deal with the implementation of vitality	(1) Papers that are duplicated within the search documents (2) Papers that make no mention of vitality practice (3) Papers that are not accessible (4) Papers that are not primary/original research

Results

Using the standard template used for data extraction, the information and results of these 36 review articles are summarised in Table 2. For each article included in this review, details such as the title, author, year of publication, object type, study area, data collection method, and related practice fields were recorded. Among the 36 articles examined in this review, the highest number, comprising 18 articles focused on streets as a neighbourhood scale, as depicted in Figure 2. A few studies explored neighbourhoods, parks, and metro stations as models. It is noteworthy that the majority of empirical studies were situated in China, as depicted in Figure 3.

Research Subject

From a statistical perspective, the study was classified into four categories encompassing the neighbourhood, streets, park, and metro stations within the community's boundaries. These spatial typologies served as crucial units for urban vitality enhancement initiatives. Currently, there was stronger focus on analysing vitality at the street level in cities and neighbourhood-scale vitality enhancement required targeted guidance for the type of area and population involved. While some studies had assessed urban areas and contrasted the qualities and factors that influenced vitality between suburbs and urban centres (Xiao *et al*., 2021), studies on suburbs were scarce, covering small cities only with rural communities (Liu *et al*., 2022; Rui & Li, 2024).

Simultaneously, public space assessments remained predominant, whereas assessments focusing on specific population groups constituted a minority. The following groups were examined: The middle and upper classes, individuals without household registration, residents lacking property titles, original inhabitants of historic areas, and low-income farmers in traditional rural areas (Zumelzu & Barrientos-Trinanes, 2019; Li *et al*., 2021; Liu *et al*., 2022).

The vitality of neighbourhood-scale areas encompassed various dimensions, with spatial considerations, notably the built environment, playing a pivotal role as illustrated in Figure 4. Numerous studies had explored the impact mechanisms (Wu *et al*., 2021; Han *et al*., 2023; Zou *et al*., 2023) and assessment techniques (Wu *et al*., 2018; Niu *et al*., 2021) from this perspective. However, several studies had focused on non-spatial factors such as the economic vitality of business districts in small towns (J. Wu *et al*., 2018; Van Leuven, 2021), the preservation and developmental vitality of traditional rural areas (Liu *et al*., 2022; Rui & Li, 2024; Song *et al*., 2024), and the organisational vitality of communities, parks, and recreation (Wang & Vermeulen, 2021; Rui & Li, 2024).

This study found that neighbourhood-scale vitality assessments did not specifically

Table 2: Characteristics and basic information related to the selected work

No.	Authors and Year	Object Type	Study Area	Data Collection	Geo-unit	Related Practice Field
1	Wu *et al*. (2018)	Neighbourhood	China	Geospatial data, GPS, POI	Neighbourhood	Policy, Planning
2	Ye *et al*. (2018)	Neighbourhood	China	Geospatial data	Block	Planning
3	Zumelzu & Barrientos-Trinanes (2019)	Neighbourhood	Chile	Geospatial data	Building block	Planning, Design
4	Qi *et al*. (2020)	Street	China	Heat map data	Less than 100 m	Planning
5	Wang *et al*. (2020)	Park	China	Mobile phone signalling data, POI	500 m and 500-1,000 m buffer of waterfront	Planning
6	Zhu *et al*. (2020)	Park	China	Volunteered check-in data, POI	Park	Planning, Design
7	Xia *et al*. (2020)	Street	China	POI, map data, NOAA/NCEI data, VIIRS DNB data, check-in data	Building block	Planning, Policy
8	Xiao *et al*. (2020)	Metro station	China	Road network data, POI	600 m buffer of the station	Planning, Policy
9	Chang-Deok (2020)	Neighbourhood	Korea	Mobile phone data	Polygon unit	Planning
10	Zacharias (2020)	Street	Hong Kong (China)	Pedestrian flow data	Tramway stops	Management
11	Xiao *et al*. (2021)	Metro station	China	Multi-source data	600 m buffer around metro station entrances	Planning, Design, Policy
12	Mu *et al*. (2021)	Park	China	Heat map data, POI	NA	Planning, Design, Management
13	Xu & Chen (2021)	Metro station	China	POI	Building block	Design
14	Niu *et al*. (2021)	Park	China	Heat map data, city map data	Street block	Planning
15	Dong *et al*. (2021)	Metro station	China	Multi-source data	Metro lines and stations	Planning, Design, Management
16	Li *et al*. (2021)	Street	China	Built environment data, microclimate data, pedestrian flow data	Building block	Planning, Design
17	Guo *et al*. (2021)	Street	China	Multi-source big data	Street segment	Planning

18	Yang *et al*. (2021)	Street	China	Street-view images data, POI	Street block (Traffic analysis zone)	Planning
19	Wu *et al*. (2021)	Street	China	Mobile location data	Building block	Planning, Design
20	Van Leuven (2021)	Neighbourhood	United States	Multi-source data	Business districts	Policy, Management
21	Wang & Vermeulen (2021)	Street	The Netherlands	Street view image data	Building block	Planning, Management
22	Liu *et al*. (2021)	Park	China	Real-time Tencent user density data, POI, building vector data and road network data	Street block	Planning, Design
23	Jiang *et al*. (2022)	Street	China	Multi-source urban data	Street segment	Planning
24	Liu *et al*. (2022)	Neighbourhood	China	Weibo check-in data, POI, city map data	Neighbourhood	Planning
25	Wu *et al*. (2022)	Street	China	Open street map, POI	Street segment, with a buffer of 10 m on both sides	Planning, Design
26	Lee & Kang (2022)	Neighbourhood	Korea	Spatiotemporal big data	Dong as the unit	Planning
27	Istrate (2023)	Street	China	Geospatial data	Street segment	Planning, Design
28	Yang *et al*. (2023)	Street	China	Open Street Map, POI	Street segment	Planning
29	Lu *et al*. (2023)	Street	China	Multisource urban data	Street level	Planning
30	Huang *et al*. (2023)	Street	China	Open Street Map, POI	Street in historic districts	Policy, Design
31	Ma (2023)	Street	China	Street View Map, road network data, land use data, POI	Street segment	Planning, Design
32	Zou *et al*. (2023)	Street	China	Heat map data, POI, 3D building data, street view image data	Historical building block	Planning
33	Han *et al*. (2023)	Street	China	Multisource urban data	Street segment	Planning
34	Zhang *et al*. (2023)	Street	China	Wi-Fi data	Street segment	Planning
35	He *et al*. (2024)	Neighbourhood	China	Baidu heat map data, Geospatial data	Community	Planning, Policy
36	Rui & Li (2024)	Neighbourhood	China	Baidu heat map data, Weibo check-in data, POI, NDVI, city map data	Urban village	Planning

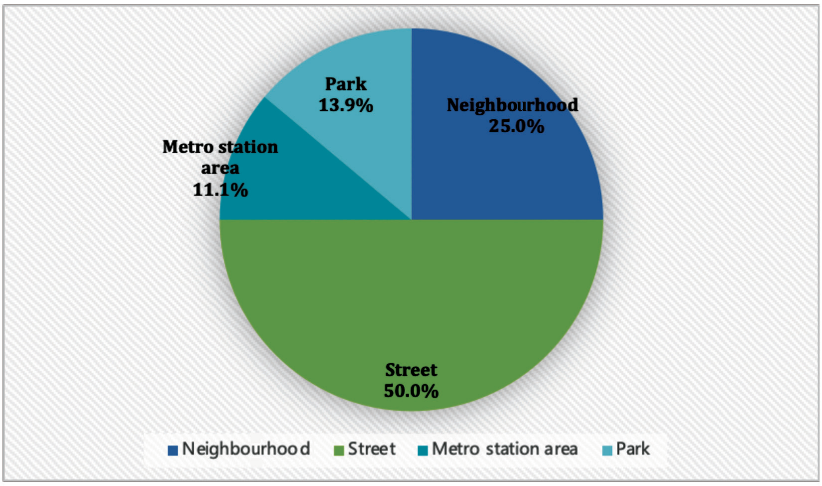

Figure 2: Space type proportion of the research subject
Source: The author

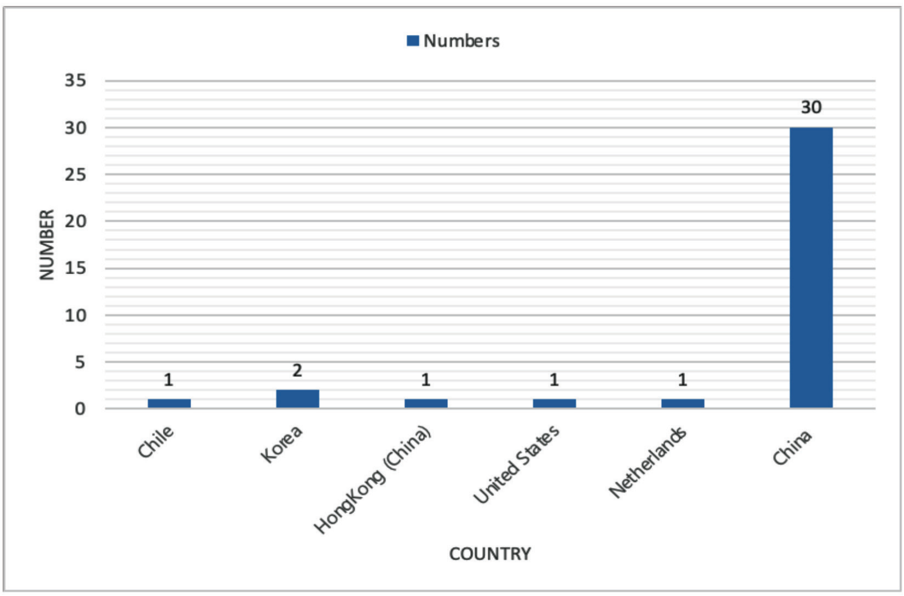

Figure 3: The number of empirical studies in different countries of selected articles
Source: The author

focus on multi-temporal vitality. The focus of these time division investigations was the distinctions in characteristics between weekdays and weekends. The study also found that weekday and weekend impacts were primarily related to commuting, with most elements of the built environment having a greater impact on weekends (Wu *et al*., 2018). The literature discussed the impact of weekdays and weekends on neighbourhood vitality in time and space and suggested avenues for improvement such as focusing on the increased demand for travelling to educational venues at weekends, as improved accessibility could significantly enhance weekend neighbourhood vitality (Yang *et al*., 2021).

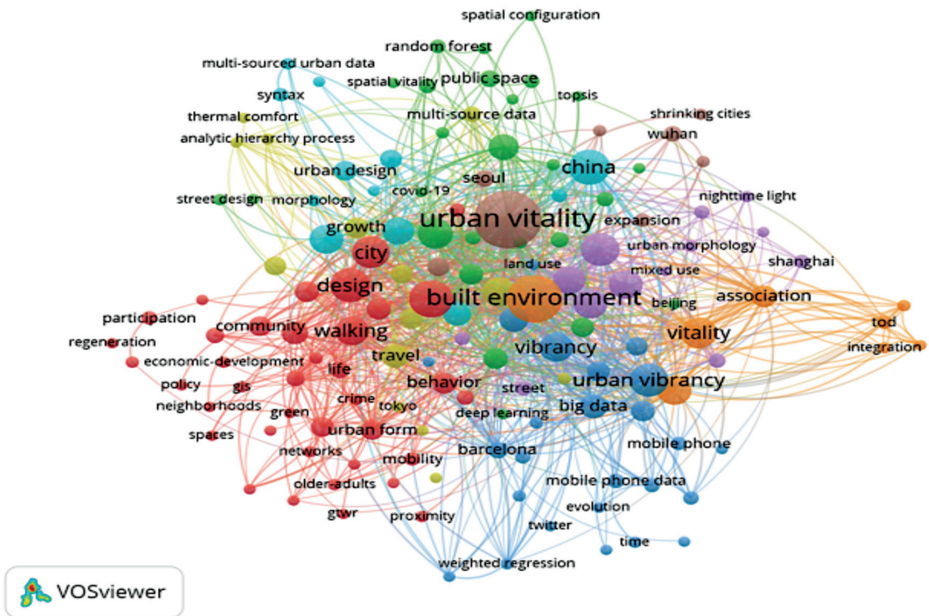

Figure 4: Keyword co-occurrence network of urban vitality
Source: The author based on VOS viewer

Statistically, most of the current literature focused on research to optimise assessment methods. Studies had mainly focused on spatially aware methods for optimising the characteristics of small-scale communities to obtain a better degree of precision and to be closer to reality. However, there were very few researches on optimising vitality practices to improve policy and management.

Research Methodology

At present, there are two primary types of measures for assessing vitality at the neighbourhood scale: Single-factor and multi-factor integration, as illustrated in Figure 5. Increasingly, studies are adopting multi-factor fusion approaches. Among these, methods that leverage human flow or activity per unit area had gained popularity. Nevertheless, traditional methods, which utilise the number of people on-site per unit of time and space, remained practical (Xu & Chen, 2021). Recent investigations had commenced to augment instrumental monitoring to acquire travel data that were more precise. For example, researchers had used long-term and in situ repeated measurements generated by urban sensors to extract pedestrian counts as a representation of the vitality of historic districts (Li *et al*., 2021). Some researchers asked respondents to wear GPS tracking devices and used the percentage of their out-of-home, non-work activities to define community vitality (Wu *et al*., 2018). Overall, these methods provided a truer and more accurate picture of pedestrian numbers, thus, contributing to neighbourhood-scale vitality.

In addition, the integration multiple vitality factors were another common approach. Numerous studies had investigated the elements of vitality through the development of an indicator system and the weighting and computation of multi-source data fusion, which included built environment, statistical, and location-based data. Additionally, we found that other studies combined the vitality survey scores with on-site images (Qi *et al*., 2020), which were optimal for massive data processing and brought spatial vitality recognition closer to genuine perception.

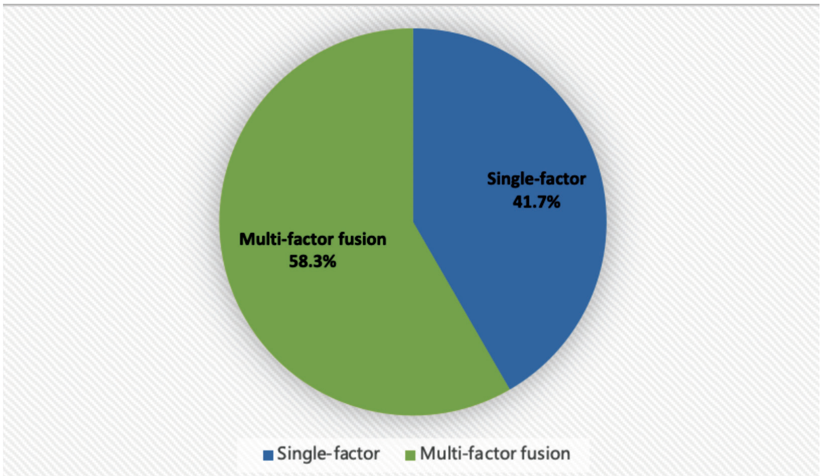

Figure 5: Neighbourhood-scale vitality measurement used in the 36 selected articles

Location-Based Services (LBS) data played a crucial role in comprehending people's behaviour across different environments (Huang *et al*., 2018). It served as the foundational data upon which neighbourhood-scale vitality research relied on, with 78% of studies utilising it, as depicted in Figure 6. As information and location technology continue to integrate, LBS data, including POI, social media, and mobile phone data, had become extensively employed in studies related to urban vitality. In the literature, these vast real-time datasets depicting human activities had introduced novel surrogate indicators. For instance, the density of social media check-ins could serve as a proxy indicator, capturing the level of interaction between individuals and urban spaces. Such location check-ins recorded individuals' activities at specific locations, thereby delineating the intensity of human engagement (Liu *et al*., 2021; Liu *et al*., 2022). Furthermore, POI could offer insights into land use intensity and functional

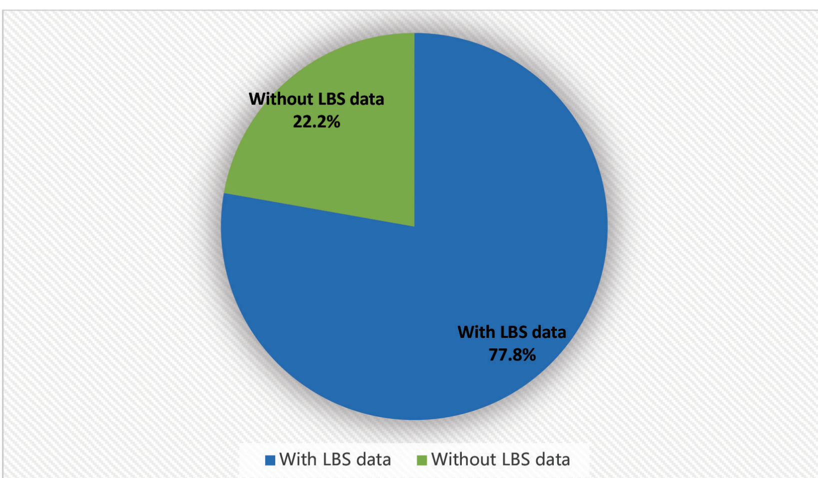

Figure 6: Categorisation of 36 articles used location-based services data
Source: The author

diversity, further enriching vitality assessments (Liu *et al*., 2022; Huang *et al*., 2023; Ma, 2023; Rui & Li, 2024).

Motivators of Urban Vitality

This study analysed the influencing factors of four type of spatial entities: Blocks, streets, transit-oriented developments, and parks. The influencing factors explored were primarily at the planning level in three primary domains: Socio-economic, built environment, and function. The built environment was the majority common influence variable. Each form of spatial entity was thoroughly researched, with a focus on spatial factors like size, density, accessibility, and connectedness (Ye *et al*., 2018; Li *et al*., 2021). Function was also a rather well-studied field of influencing variables, with emphasis on the type, density, and diversity of services (Guo *et al*., 2021; Niu *et al*., 2021; Xu & Chen, 2021). In addition, a few planning-level studies had extended the mechanisms driving vitality to socio-economic, concentrating on the influence of socio-economic circumstances, such as population, employment, work, money, and property rights on urban vitality (Wu *et al*., 2018; Chang-Deok, 2020).

There were limited studies on design and management-level influences. The design level drivers were mainly from a visual sensory perspective, focusing on small-scale problems with facility design, green space, and layout. Most of the management-level impacts were related to commercial dimensions such as per capita spending, opening hours (Jiang *et al*., 2022; He *et al*., 2024).

Furthermore, linear impact studies were the primary means of observing the effects of a variety of factors on vitality. Researchers found trends of beneficial effects of accessibility, land use mix, and transit access (Guo *et al*., 2021; Niu *et al*., 2021; Huang *et al*., 2023; Lu *et al*., 2023; Zou *et al*., 2023) on neighbourhood-scale vitality. There were fewer studies on non-linear and synergistic effects of vitality factors (Xiao *et al*., 2021; Han *et al*., 2023). A large number of studies on non-linear effects were still in the hypothesis stage. Some studies speculated that high accessibility might have a negative impact on park use when park safety and management levels were low (Xiao *et al*., 2021).

Statistically, there were many recommendations for planning practices, mostly based on quantitative analyses of influencing factors. In summary, by examining the research subjects, methods, and motivators, this study had identified gaps between research and practice as summarised in Table 3.

Table 3: Gaps between urban vitality planning research and planning practice

Type	GAP
Subject	Location category: Suburban
	Space category: For a particular demographic group
	Dimension: Non-spatial vitality
	Time intervals: Night-time
	Assessment objectives: Implementation with adaptability
Method	Measure of vitality: Genuine perception and interaction
	Data: For vulnerable populations
Motivators	Design aspects: Aspects of multisensory spatial design
	Management aspects: Non-commercial aspects of management
	Mechanism: Synergistic effects

Case Study

Xishan is a district in Wuxi with a total area of 399.11 square kilometres. Located in the suburbs of the city, Dongting Road, with a total length of 8 km is an important traffic artery in Xishan. This article adopted the neighbourhood as a research unit. A section of the road from Yanyang Road to Chunhu Road, which spanned three neighbourhoods including Dongting, Yunlin, and Dongbeitang was chosen as the research scope (Figure 7). This neighbourhood is both an important belt for the development of social life and a key transport hub connecting Xishan with the city centre.

In existing literature, the quantification of urban vitality typically fell under two theoretical categories. The first was rooted in Jacobs' diversity theory, which employed population size or density, as the primary measure. This approach included metrics such as social media check-in density, mobile phone subscriber density, and big data population density (Xia *et al*., 2020; Lee & Kang, 2022; Zhang *et al*., 2023; Rui & Li, 2024). Conversely, there was another theoretical perspective that regarded vitality as a fundamental urban factor that expanded the scope of human activities. Proxies such as POI density had emerged under this framework in a bid to quantify the abundance of urban activity or land use intensity (Wu *et al*., 2022; Ma, 2023; Yang *et al*., 2023). These two theoretical approaches often intersect and complement each other and were increasingly studied as technological advancements that supported urban vitality research.

This study utilised Baidu heat map data to calculate the relative density of street population distribution as a method to describe vitality. Additionally, POI data, encompassing multiple characteristics was employed to represent the number and diversity of services available near the street.

For POI data collection, Python software was utilised to access the API interface of the Gaode Map open platform, retrieving POI data within a two-kilometre radius of Wuxi and Dongting Road. The collected POI were categorised by functional type (e.g., commercial, public service, residential, leisure) and imported into ArcGIS for spatial analysis. Kernel Density Estimation (KDE) was applied to generate a POI density map, which visualised the spatial distribution and intensity of service facilities across the study area. Regarding heat data collection, Baidu Maps was employed to track heat levels during the week of January 15th to January 21st, 2024.

Data was collected at regular intervals across four time periods: 9:00-10:00, 12:00-13:00, 17:00-18:00, and 20:00-21:00. To ensure representation, Monday and Saturday were selected to respectively represent weekdays and weekends. The heat map raster data were subsequently analysed using ArcGIS to identify spatial hotspots and explore their correlation with the distribution of surrounding services. To facilitate temporal comparisons, population density data (measured in people/hour/km^2) were visualised using colour-coded gradients across different time periods.

The study initially analysed POI data across Wuxi, yielding a total of 121,483 POI within city limits. The analysis revealed that the southern section of Dongting Road fell within the commercial catchment area radiating from the city centre, drawing individuals from this direction (Figure 8). Consequently, future regeneration and renewal efforts should prioritise upgrading the function and environment in this area.

Subsequently, the study focused on analysing POI data within a two-kilometer radius on both sides of Dongting Road, visualising a total of 39,979 POI. Although pockets of high thermal activity were observed in the northern part of the street, the spatial vitality of the southern section markedly exceeded that of the central and northern segments (Figure 8). This disparity could be attributed to the southern section's predominantly residential character and relatively comprehensive amenities, contrasting with the industrial nature of the northern section. Considering these findings, the implementation process could benefit

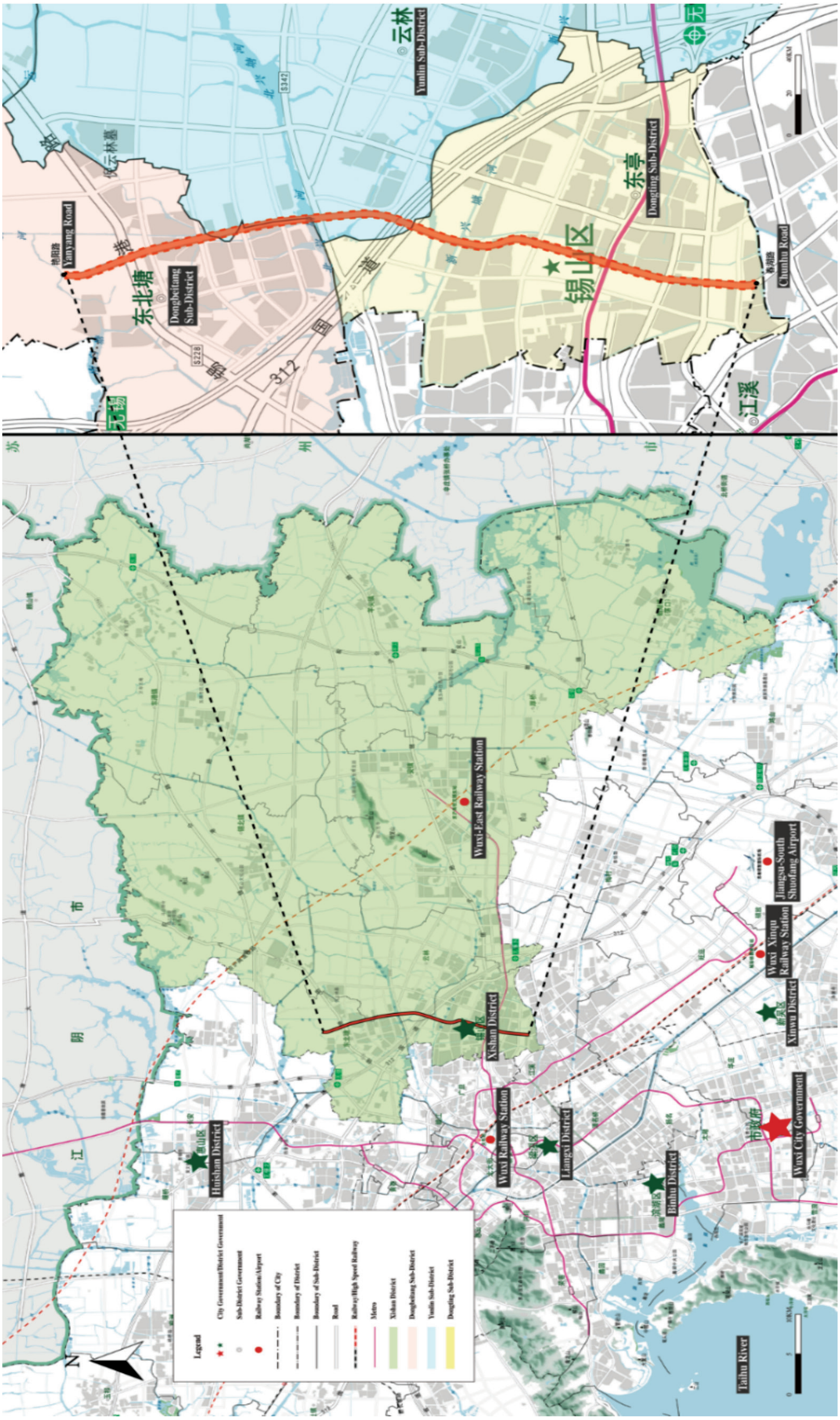

Figure 7: Partial map of Wuxi in Jiangsu province, China, showing the location of Dongting Road in Xishan district

Source: The author based on Standard Map of Wuxi

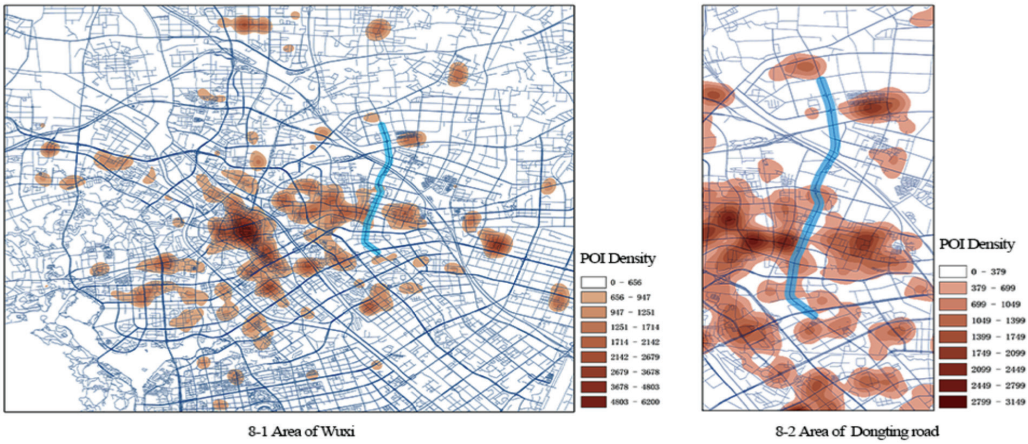

Figure 8: Map of POI density in Wuxi and Dongting Road

from efforts to enhance ancillary facilities in the industrial zone, including restaurants and transportation infrastructure.

Using the concept of 10-minute living circle, which had broader value (Logan *et al*., 2022), 7,885 POI within one-kilometre of Dongting Road were obtained by calling the Gaode Map Open Platform API interface using Python software. The POI were categorised into 10 functional types: Shopping, restaurant, leisure and entertainment, accommodation, sports facility, education and research, transportation, life service, medical service, and park and attractions (Table 4). Analysis of POI distribution

Table 4: Points Of Interest (POI) classification in Dongting Road

Facility Sort	Facility Subdivided	Quantity of POI
Shopping	Shopping centres, supermarkets, vegetable markets, commercial streets, convenience stores, home appliance stores, building materials markets, department stores, flower, and bird markets	3,432
Restaurant	Hotel, restaurant, dessert shop, coffee shop, milk tea shop, fast food restaurant, snack bar	1,514
Leisure and entertainment	Singing room, playground, cinema, bar, chessboard room, Internet bar, teahouse, spa shop	106
Accommodation	Guesthouse, apartment, hotel, hostel, holiday house	98
Sports facility	Fitness, badminton, football, basketball, swimming, yoga, martial art	72
Education and research	Kindergarten, primary school, senior high school, high school, university, early education centre, library, museums, exhibition halls	332
Transportation	Bus station, subway entrance and exit, motor station, railway, car parking	566
Life service	Manicure, repair services, post offices, laundries, photo studios, housekeeping services, public utility service stations, logistics stations, laundries, public toilets, telecommunication offices, lotteries	1,398
Medical service	Hospital, pharmacy, clinic, community health centres, and health service stations	339
Park and attractions	Park, square, attractions	28

(Figure 9) revealed that the predominant types of facilities around Dongting Road were restaurants and shopping establishments, indicating a high demand for dining and retail experiences among local consumers.

Furthermore, the density of life service facilities surrounding the street was relatively uniform, effectively meeting residents' daily needs. Transportation facilities in the vicinity were also abundant and convenient. However, there was notable scarcity of leisure and entertainment facilities, suggesting a lack of recreational diversity in this area. Additionally, parks, squares, and fitness facilities along the street were relatively limited, indicating room for improvement. The vitality of the street and the flow of people throughout the day could be visualised using heat maps. Firstly, analysis of heat map data for four time periods on weekdays (Figure 10) revealed that two metro stations, Baizhuang and Dongting exhibited higher heat values during the daytime. Heat values in public spaces such as commercial areas and parks remained relatively consistent across the four time periods, while most points in the neighbourhood experienced a notable increase in heat values around 18:00. Secondly, in the heat map depicting rest days (Figure 11), the Baizhuang metro station stood out with the highest heat value across the four time periods. Additionally, compared to weekdays, there was a discernible upward trend in the heat value of commercial areas on rest days.

A comprehensive analysis of heat map data was conducted for different time periods on weekdays and rest days. Firstly, it was observed that areas with high heat values in Dongting Road were primarily concentrated in the central and southern regions, indicating an imbalance in service provision between the southern and northern areas. Secondly, points with higher heat values were predominantly situated in areas with high foot traffic such as transport hubs, suggesting that residents in the neighbourhood were more inclined to pass through these areas rather than linger.

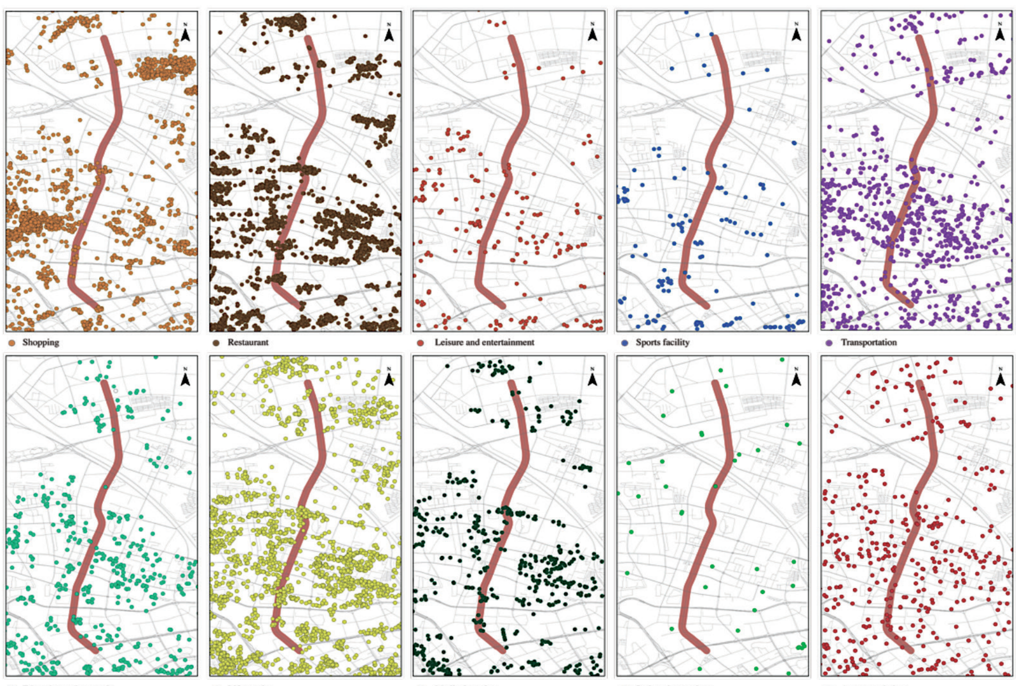

Figure 9: POI facility sort distribution map around Dongting Road

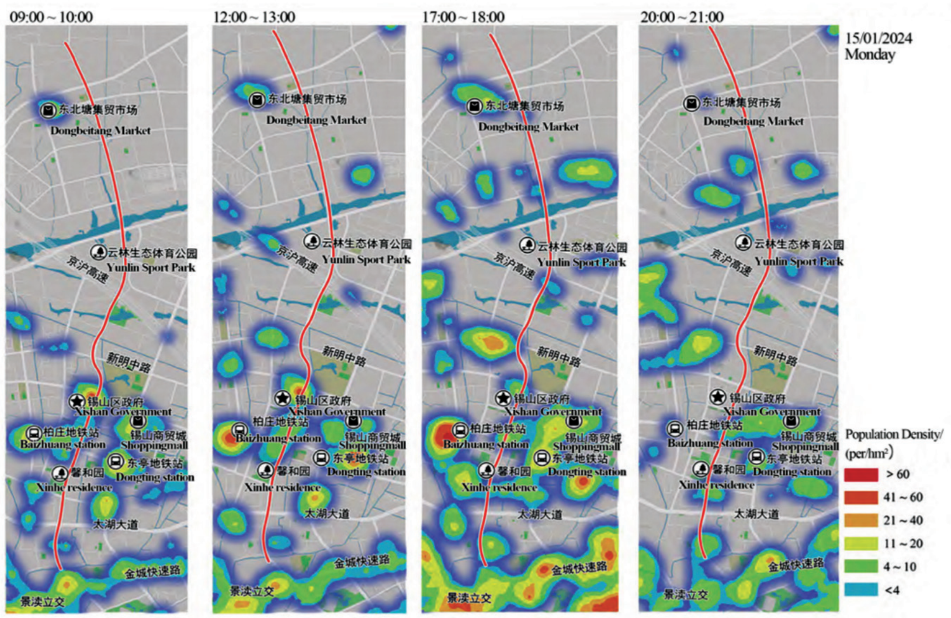

Figure 10: Heat map around Dongting Road on weekdays

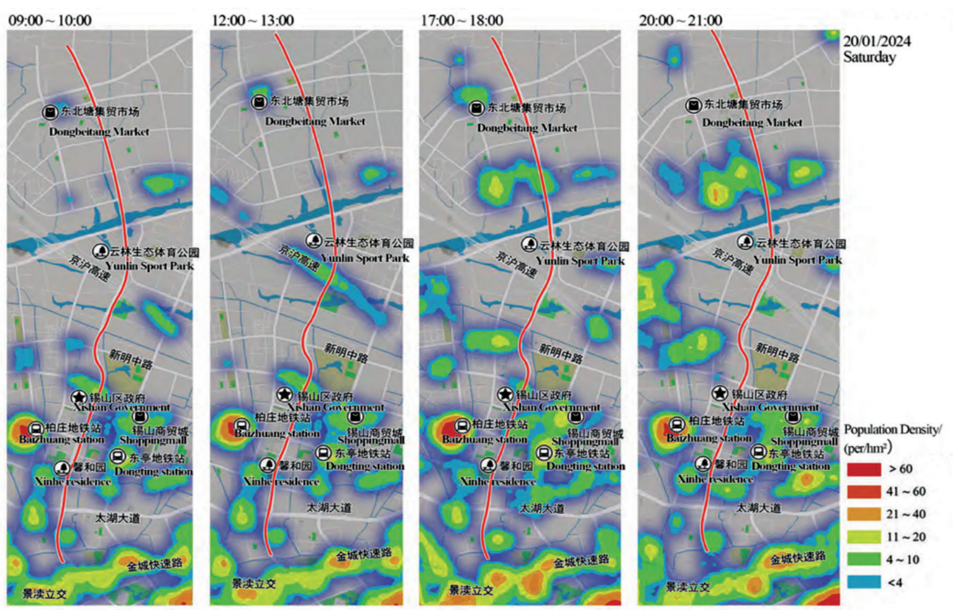

Figure 11: Heat map around Dongting Road on rest days

Thirdly, the distribution of heat values within the neighbourhood exhibited different patterns between weekdays and rest days. On weekdays, heat values were more sporadically distributed, with higher values observed in residential areas. On rest days, the values were relatively concentrated, primarily around metro stations and commercial areas. Notably, the Baizhuang metro station registered significantly higher heat values on rest days due to its proximity to large shopping malls. Fourthly, the heat values at public activity spaces remained low, with no significant change observed on weekdays or rest days. This suggested that the spaces were not sufficiently utilised.

This case study evaluated neighbourhood-scale vitality using POI and heat maps. Overall, from a practical standpoint, it was evident that the presence of rich and diverse facilities offering various services could foster increased pedestrian activity and enhance the vitality of the street environment. Furthermore, the research demonstrated that Baidu heat maps were effective tools for studying vitality at different times of the day, including night assessments.

Discussion

This section would address identified gaps between research and practice and propose research components and technical approaches to bridge the disparities. Primarily, existing disparities primarily arising from diversity of research topics, the accuracy and thoroughness of vitality assessments, and the multidimensional nature of impact factor analyses were highlighted.

Expanding the Subjects of Research

The current discourse on neighbourhood-scale vitality primarily centres on evaluating public spaces in urban centres and their vitality across various spatial dimensions, employing increasingly refined optimisation methods. Despite its broad coverage, there remained a notable gap on the suburbs, particularly regarding the diversity of neighbourhood types.

In this study, streets in the suburbs of Wuxi were selected for vitality assessment. Suburban neighbourhoods in metropolitan areas often faced unique challenges such as poverty, ethnic incompatibility, and inadequate facilities, which might necessitate targeted interventions (Liu *et al*., 2022). Furthermore, there was a need to broaden the spatial typology of neighbourhood-scale vitality studies to encompass specific population demographics and their living environments. For instance, future research could explore the vitality of spaces such as university towns inhabited by young people, industrial parks populated by workers, scenic areas frequented by villagers and tourists, and gerontological neighbourhoods catering to the elderly.

By supplementing these specific spatial analyses with targeted research, the relevance of classifying practice decisions and developing tailored strategies to address the unique needs and challenges of diverse urban communities could be enhanced. Additionally, expanding the scope of neighbourhood-scale vitality research to include suburban areas and specific population-centric spaces could contribute to a thorough comprehension of urban vitality besides fostering inclusive and equitable urban planning and development practices.

The vitality at the neighbourhood level is influenced by urban activities and interactions (Yue *et al*., 2017). Current evaluations mainly concentrated from a spatial standpoint on the built environment while non-spatial studies were limited to economy, culture, conservation, and development (Vandenbussche, 2018; Wang & Vermeulen, 2021; Liu *et al*., 2022). Research on specific dimensions of vitality should be increased and tailored to explore various characteristics, incorporating influences from a variety of perspectives to provide effective guidance for small-scale vitality enhancement initiatives.

In order to improve the vitality of a neighbourhood, it was essential for research to suggest guidelines, planning, and design strategies that were specifically designed for various time periods. While existing studies had demonstrated significant variations in vitality between weekdays and weekends, with commuting patterns playing a key role, there was a notable dearth in research specifically focusing on night-time vitality. Evening hours represented a pivotal time when employed individuals and school-age populations return to their neighbourhoods and engage in social activities. While night-time vitality had been studied on the urban scale (Kim, 2020; Zhang *et al*., 2021; Wu *et al*., 2023), its precise measures and drivers might necessitate further investigation. This could involve pre-analysing residents' night behavioural patterns and initiatives.

This might require pre-analysis of the numerous night time behavioural attempts of inhabitants. In addition, studies were also needed on community vitality emergency or disaster such as heavy rains, typhoons, and epidemics. Studies investigating changes in urban vitality with the presence of healthy environments and attitudes towards urban living during pandemics were available (Zordan *et al*., 2023). However, the factors that influenced the vitality of neighbourhoods during different types of crises remained obscure and should be classified to assist communities on how to handle emergencies.

Little consideration had been given to evaluate the applicability of research to practice such as policymaking and urban planning. Therefore, future research could optimise evaluation objectives in relation to local urban regeneration plans such as zero-energy neighbourhoods, child-friendly neighbourhoods, and revitalisation of historic districts, to adjust them to specific planning guidelines, practices, or policy management.

Therefore, in future research, the following perspectives could be considered. First, expand vitality assessment to multi-modality concepts, especially for population-specific suburban communities and neighbourhood spaces. Second, expand spatial vitality assessment to multi-dimensionality concepts, from numerous non-spatial views illustrated in-depth features of social interaction to community organisation. Third, investigate multi-temporal vitality, especially precise assessment of neighbourhood night-time and crisis-moment vitality, which might need pre-analysis of a range of time-specific behavioural initiatives of inhabitants. Fourth, expand target assessments to implement adaptive assessments, which might require in-depth surveys and analyses of specific practice guidelines and policies.

Moreover, the spatial and temporal variations identified in this study such as the differences in vitality between weekdays and rest days or the low levels of activity during evening hours had practical implications for urban design. For instance, reduced vitality in the evening might indicate the need to improve lighting conditions, create leisure spaces, or introduce services that catered to night-time use to activate public areas after typical working hours. In contrast, increased activity on weekends might signal the necessity of enhancing pedestrian infrastructure and expanding service capacity. These insights emphasised the importance of aligning design and planning strategies with specific time periods and behavioural patterns, thereby fostering more responsive and inclusive neighbourhood environments.

Expanding Methodologies

Current neighbourhood-scale vitality measurements were mainly based on human flow or activity per unit area (Chang-Deok, 2020; Zhang *et al*., 2021; Jiang *et al*., 2022). These methodologies were inadequate for explaining the behavioural interactions or the true experience of spatial life in small-scale places. With the increasing integration of information and location-based technologies, these indicators had better spatial, temporal, and dynamic characteristics, but there were still limited in data sources.

For example, most users of social media platform check-ins were young and underrepresented among the elderly; POI data were difficult to and data on night-time lighting had limited resolution that characterised only the night-time vibrancy of a city. Since social interactions could serve as an indicator of urban vitality (Yue *et al*., 2017), further research would be required to determine how to precisely assess them at the neighbourhood level and to surmount the challenges and complexities associated with their quantification.

Since mobile phone usage among children and older adults was limited, location data might not effectively capture the mobility patterns and social interactions of these populations. Nevertheless, empowerment initiatives often prioritised creating inclusive spaces for these people, particularly in older communities and neighbourhoods around kindergartens and primary schools. Consequently, it would be imperative for future research to investigate data and methodologies that authentically represented the social interactions and mobility of vulnerable groups. This approach would broaden the scope of individuals examined in current research efforts. First, there is potential to simulate the measurement of real perceived behavioural interactions using virtual reality techniques. Second, measurement studies can be specifically tailored to vulnerable groups, necessitating the integration of new technologies.

Therefore, vitality data should not only reflect spatial-temporal patterns but also inform practical design strategies. For instance, low-vitality zones could prompt improvements in accessibility or public space programming, especially for vulnerable groups. Temporally uneven areas might benefit from flexible-use designs or time-sensitive interventions. Embedding such interpretations into planning could enhance neighbourhood inclusiveness and responsiveness. For example, the "Child-Friendly Cities" initiative in several Chinese municipalities had led to the incorporation of play-based spatial designs and safety zoning in neighbourhood planning (China National Development and Reform Commission *et al*., 2021).

Enhancing Motivators

Currently, research on the drivers of vitality was focused on the linear impact of single factors from a planning perspective, which was lacking in design and management impacts.

The design factors being proposed in the literature were primarily based on the visual senses, including layout, scale, green space, and facility design. There was relatively little mention on aspects that influence multi-sensory spatial design. Future studies should focus on the diverse sensory design components incorporated in design codes and standards. For instance, they might examine the effects of landscaping, water features, colour, special facility design, and vegetation on vibrancy as perceived through the senses of sight, sound, and touch. By assessing an adequate variety of spatial design aspects and providing targeted standards and normative improvements, the study would provide clear and powerful practical guidance for implementing vitality enhancement practices.

The management-level influences in the current study were mainly related to commercial dimensions such as retail rents, per capita consumption, and business hours. There was still a dearth of dimensions targeting health and services for disadvantaged groups. This study proposes that future research should focus on the following management dimensions: First, improving social security, focusing on the intensity of management, and improving the coverage of monitoring systems. Second, dimensions related to health management could be considered to improve water quality, waste management, and road drainage. Third is to consider dimensions related to management of services for vulnerable groups, including mother and baby rooms, spaces for the elderly and playgrounds or children.

Currently, only one study evaluating neighbourhood-scale vitality in transit-oriented development areas had considered the synergistic effects of various factors, including the consequences of building height, street centrality, bus route density, and street bypass ratios (Xiao *et al*., 2021). In practice, it was impossible to enhance a specific indicator in isolation. How to organise the several impacting aspects to attain the objective of improving vitality would become a challenge in the implementation process. Therefore, it was imperative to investigate the effects of multiple influencing elements on vitality under realistic constraints.

To enhance the applicability of vitality research, future studies should move beyond linear factor analysis and explore how design and management strategies can work in synergy. For example, identifying effective combinations of spatial design elements such as greenery, acoustic comfort, and inclusive facilities could support the development of adaptable design codes suited to various neighbourhood types. For example, the "15-Minute Community Life Circle" policy (Shanghai Municipal Government, 2022; Shanghai Urban Planning and Land Resources Administration Bureau, 2025) was designed to integrate diverse services, green infrastructure, and active mobility into small-scale neighbourhoods. These initiatives illustrated how multi-sensory spatial design and inclusive service management could be institutionalised in planning policies.

Conclusions

There is an imperative need to shift focus from merely evaluating urban vitality to effectively implementing it—an aspect that has received insufficient attention in current literature. By centring on a neighbourhood scale, deemed optimal for implementing vitality assessment, the study endeavours to ensure that its findings can be readily applied in relevant practices.

Through a systematic literature review and case study, the gap between existing research and practical application has been identified, which is primarily attributed to the diversity of study subjects, the authenticity and comprehensiveness of vitality measurements, and the multi-domain nature of impact factor analysis. The study posits future research directions, including multidimensional neighbourhood-scale vitality assessment, focusing on social interaction and vitality measurement methods for disadvantaged groups, exploring the role of design and urban management in enhancing vitality, and investigating the impact of multiple indicators on vitality. Nonetheless, there are limitations, particularly the scarcity of literature addressing implementation-related neighbourhood-scale vibrancy evaluations. Despite these limitations, the study offers valuable insights into studying neighbourhood-scale vitality and provides guidance for future research aimed at expediting vitality implementation.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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