PEAK Urban

Beyond density: New insights from big data computation and social sensing in urban science

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Time and space measures of urban metrics could transform our way of understanding cities in the era of big data computation. Conventionally, density (for example, in terms of population, buildings or roads) has been used to describe the built environment in urban development. However, as urban expansion continues and urban structure becomes more complex, density itself can no longer provide a comprehensive measure of cities. In this briefing, we describe how the new urban sciences facilitate more nuanced descriptions of the urban morphology through which cities are compared. Our research explores which metrics – both static and dynamic – are most appropriate to reflect urban characteristics instead of density. We also use new data sources to explore how people feel about their city in different times and places.

Novel understanding of urban forms and emotions

According to the classic text "Garden Cities of Tomorrow",[1] which provides a vision of cities enjoying benefits of both town and country, a central city with 58,000 inhabitants is deemed ideal for balancing urban residents' wellbeing and prosperity. However, this scale and size are not applicable to today's high-density cities, which require analysis beyond the spatial settlement classifications of urban or rural, big or small, or straightforward measures of density of the built environment. Contemporary cities can best be profiled through emphasising "place-making". By making visible the workings of the city in real time, we can begin to understand the "intensity" of city life, rather than simply its density.

Urban intensity is a measure of multiple spatial dimensions of cities, such as compactness, diversity, density and connectivity, which together, via a composite score, provide a single index to compare cities' spatial layouts. By establishing measures of urban intensity, we can carry out a comprehensive assessment of urban morphological conditions. The framework of urban intensity measures includes analytical consideration both of current urban features and those planned for the future, conceptualised in terms of time and space.

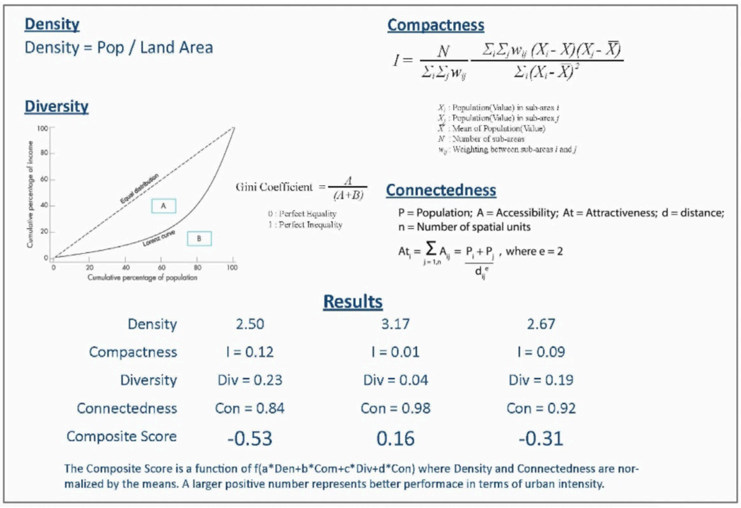


Figure 1. Methods for deriving urban intensity metrics

Our research also takes a perspective new to urban science, through the lenses of urban emotions, smart mobility and city diagnosis systems. This framework provides valuable insights to inform policymaking for building smart digital cities. We examine technical innovation and explore how machine learning and artificial intelligence can contribute to urban big data computation and urban science. Through this approach, using new data and an innovative methodology, our research explores how people think about their cities in real time, and the different ways in which they use or move around them.

1. "Garden Cities of Tomorrow", Ebenezer Howard, London, 1898.

Enriched urban profiling: compound measures of intensity

Urban intensity provides a more comprehensive measuring system to assess urban form beyond the density measure. Among the forces that shape urban formation in cities and towns, understanding of optimum urban intensity appears useful when considering resultant spatial distributions with regard to resource consumption, economic opportunity, social integration and environmental performance (Guan and Rowe, 2016, p.21). In contrast to a single measure of density, application of a multi-dimensional indicator such as urban intensity provides comprehensive measures of urban forms, revealing various dimensions of the complex urban system (Guan, 2019; Guan et al., 2022, p.2).

PEAK Urban research demonstrates this enriched urban profiling. We adopted Moran's I[2] to measure compactness, improved gravity models[3] to measure connectivity, population and land parcels to represent density, and drew on the Gini inequality index to reveal diversity. Using three hypothetical models of monocentric, polycentric and linear urban form, with varying spatial arrangements of urban activities, building footprints and infrastructural elements, we validated the methodological approach. We acquired data from both online point of interests such as restaurants, hotels, schools and parks, and from field surveys supported by the local planning bureau and research institute, as shown in Figure 2.

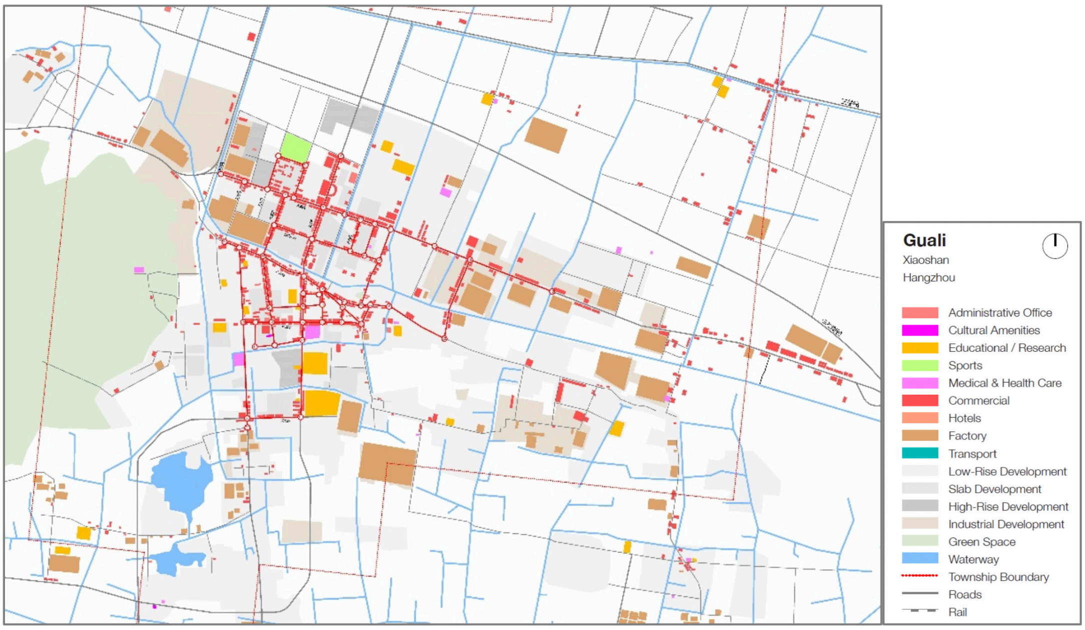


Figure 2. Data collection outcomes for profiling urban intensity

The results showed that monocentric cities with well-defined and relatively uniform grids of streets and related networks, and relatively integrated zones of land use (residential, commercial, industrial, institutional or recreational) seemed to perform best in terms of the morphological conditions measured by the composite urban intensity score. However, towns with sharp separations of uses and zones of development, often resulting in overall bifurcation of urban spatial layout, performed less well. Linear forms for small towns were also less favourable.

2. Moran's I measures spatial autocorrelation, characterised by a correlation in a signal among nearby locations in space.
3. Gravity models mimic gravitational interaction as described in the Law of Gravity.

Assessing urban intensity in China's Zhejiang Province

The research then explored whether urban planning in China's Zhejiang Province is creating better-performing towns in terms of their morphological conditions. We examined both existing urban conditions and planned conditions, using regulatory detailed planning (RDP). We also assessed the intensity of towns incorporating a green-space perspective. Figure 3 shows this research framework. Using normalised composite scores of urban intensities, the results show that the regulatory detailed planning of more than half the towns assessed does not improve their development in terms of spatial arrangement measured by urban intensity. Among better-performing towns, the contributing factors varied. For example, some towns scored high on compactness, others on diversity and accessibility.

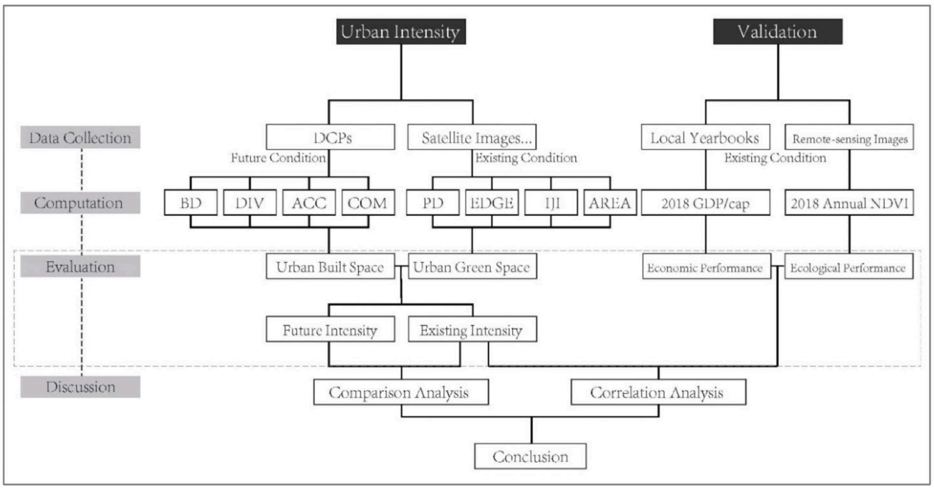
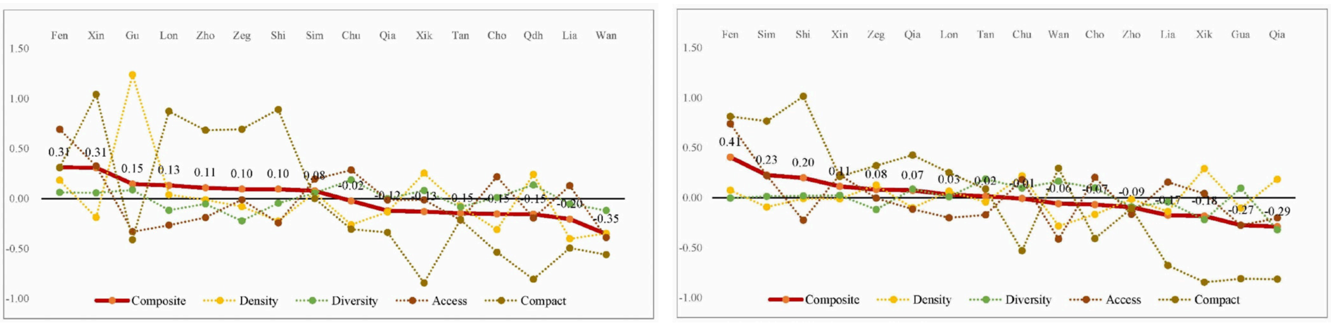


Figure 3. Research framework for assessing the intensity of towns, incorporating a green-space perspective

We also went beyond more conventional urban science methods and applied new big data sources and advanced analytical methods to test the validity of urban intensity against both economic and environmental standards, using data for GDP per capita and normalised difference vegetation index (NDVI), respectively. The validation showed that green space metrics are highly correlated to the NDVI values, indicating reliability of the selected urban green space metrics. However, the urban built space metrics are only moderately correlated to GDP, but highly correlated to GDP per capita.

This research provided an innovative framework of urban intensity metrics for balancing various urban spatial conditions and reconsidering the arrangement of urban green space in future planning. The analysis of existing urban conditions showed there is capacity to improve the overall performance of urban intensity by better balancing the development of both urban built spaces and green spaces. Figure 4 ranks the existing and planned conditions of the featured towns in Zhejiang Province.

Using new data and an innovative methodology, our research explores how people think about their cities in real time, and the different ways in which they use or move around them



a. Existing conditions

b. Planning conditions

Figure 4. Ranking of 16 towns in China's Zhejiang province, by composite intensity scores and individual variables

Innovative techniques to harvest real-time sentiment

The 21st century has seen massive urban growth in new parts of the world, with the emergence of megacities and rapid urbanisation, particularly in China. A major question for research is whether the regularities and patterns identified over decades will be repeated in the new forms of urbanisation, particularly outside the historical urban growth zones of Europe and North America. In addition, as cities across the globe develop "virtual twins"[4] – sometimes described as an "urban brain" – what will be the new relationship between the physical and the virtual globally? Will the foundational laws of the urban sciences still hold true in cities of the global South and global North alike in the wake of the Covid-19 pandemic and the era of digitalisation? In this context, PEAK Urban research considers the timescales and geographical scales at which we can predict urban futures.

New data sources allow us to measure what we might describe as "urban emotion". A rising term in the era of big data urban planning, urban emotion illustrates collective public sentiment towards certain events, measured in both time and space. An aggregated indicator, it is extracted from user-generated content such as social media. Compared to individual emotions extracted via conventional surveys, it provides more comprehensive, real-time sentiment evaluation of the urban population.

Understanding emotion to inform policy

During the Covid-19 pandemic, such evaluation became even more essential for policymaking and urban management (Bogdanowicz and Guan, 2022). Existing literature has investigated the variation of urban sentiment across various scales and under different emergency management conditions, such as total lockdown and social distancing. However, most investigations have relied on textual information only, and few apply to the field of urban planning and urban crisis management. In response, we conducted sentiment analysis to understand how people were feeling from the words they used in their Tweets, which were linked to the emotions "anger", "joy" and "frustration". For example, when the word "amazing" appears, we assume the person tweeting is experiencing "joy or happiness".

We observed that not only has Covid-19 struck the economy and public health, but it also has deep influence on people's feelings (Yao et al, 2021). As an active social media, Twitter constitutes a rich database through which we can investigate people's sentiments during the pandemic. By conducting sentiment analysis on Tweets using advanced machine learning techniques, our study aimed to investigate how public sentiments responded to the pandemic from 2 March to 21 May 2020 in New York City, Los Angeles, London and another six global megacities. Results showed that across cities, negative and positive Tweet sentiment towards lockdown policies clustered around mid-March and early May, respectively. Positive sentiments in Tweets from New York City and London were positively correlated with stricter quarantine measures, although this correlation was not significant in Los Angeles. However, Tweet sentiments in all three cities did not exhibit a strong correlation with new cases and hospitalisation rates.

These findings form the basis for a qualitative analysis of the reasons behind differences in these correlations, and discussion of the polarising effect of public policies on Tweet sentiments. The results of this study imply that Tweet sentiment is more sensitive to lockdown orders than reported statistics on Covid-19, especially in populous megacities with strong reliance on public transport. The findings therefore support prompt and effective quarantine measures during contagious disease outbreaks.

Optimising urban green space: location and sentiment analysis

The application of mobile phone location data and sentiment analysis can improve our understanding of other aspects of urban life, such as urban park catchment areas (Guan et al., 2021; Ren et al., 2022). These approaches provide useful information and methods to analyse how people use city green space, which can aid in urban policymaking, the planning, especially with regard to health and wellbeing (Guan et al., 2020).

Our research analysed call data from millions of mobile phone records to understand patterns in the use of green spaces in cities in China and Japan. Using location data for over 1 million anonymous mobile phone users in Tokyo, for example, we plotted the frequency with which people use parks in the city and the distances they travel to reach them. Big data analysis identified complex patterns in the way residents use urban green space, and significant differences between the use of large, showcase parks and smaller green spaces. In addition, Tweet sentiment analysis reveals how people feel about neighbourhoods in the city. These new techniques for mapping such large datasets can provide planners with benchmarks to understand patterns of green space use globally and compare them more easily internationally.

We found that distance alone does not explain how people use parks, but that the nature and quality of green spaces are also important factors. The findings suggest that to optimise public health in any city, planners need to complement provision of large and small parks with even smaller and more local green spaces.

Summary

To profile urban morphology, our research considered both built space and green space, addressing spatial heterogeneity at a specific scale, and investigating both existing and planned urban forms. Using machine-learning algorithms, our methods also explored urban sentiment and city dwellers' quality of life. These approaches can help policymakers and planners achieve optimum urban intensity and shape future development based on real-time understanding of city dwellers' feelings and behaviour.

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Further reading

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About us

The PEAK Urban programme aims to aid decision-making on urban futures by:

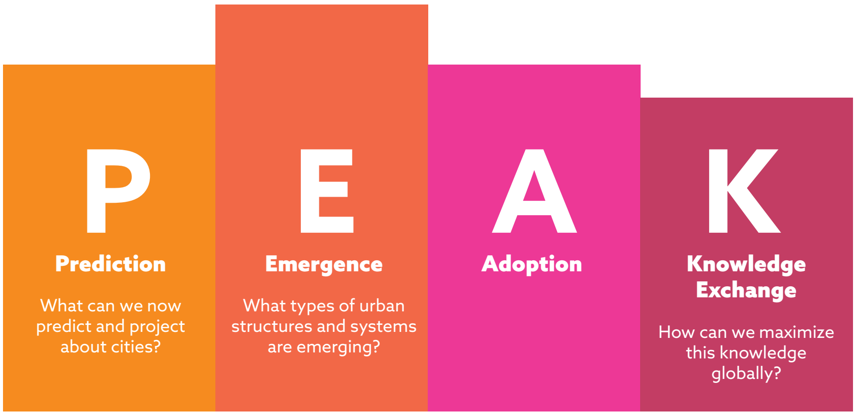
1. Generating new research grounded in the logic of urban complexity;

2. Fostering the next generation of leaders that draw on different perspectives and backgrounds to address the greatest urban challenges of the 21st century;

3. Growing the capacity of cities to understand and plan their own futures.

In PEAK Urban, cities are recognised as complex, evolving systems that are characterised by their propensity for innovation and change. Big data and mathematical models will be combined with insights from the social sciences and humanities to analyse three key arenas of metropolitan intervention: city morphologies (built forms and infrastructures) and resilience; city flux (mobility and dynamics) and technological change; as well as health and wellbeing.

Our framework



The PEAK Urban programme uses a framework with four inter-related components to guide its work.

First, the sciences of **Prediction** are employed to understand how cities evolve using data from often unconventional sources.

Second, **Emergence** captures the essence of the outcome from the confluence of dynamics, peoples, interests and tools that characterise cities, which lead to change.

Third, **Adoption** signals to the choices made by states, citizens and companies, given the specificities of their places, their resources and the interplay of urban dynamics, resulting in changing local power and influencing dynamics.

Finally, the **Knowledge** component accounts for the way in which knowledge is exchanged or shared and how it shapes the future of the city.

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