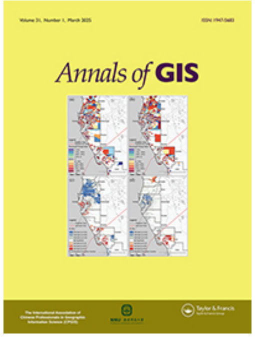

Annals of GIS

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tagi20

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To cite this article: Si Chen (2025) Deriving a measure for the environmental quality of life of an ultra-dense urban setting, Annals of GIS, 31:1, 53-66, DOI: 10.1080/19475683.2025.2453551

To link to this article: https://doi.org/10.1080/19475683.2025.2453551

Published online: 18 Jan 2025.

ANNALS OF GIS
2025, VOL. 31, NO. 1, 53–66
https://doi.org/10.1080/19475683.2025.2453551

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Deriving a measure for the environmental quality of life of an ultra-dense urban setting

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ABSTRACT
Quality of life encompasses social, economic, and environmental dimensions, with environmental indicators posing challenges due to their diverse nature. This study proposes a flexible measure of the physical environment that considers individual preferences. The research focused on neighbourhoods in Hong Kong, representing various levels of urbanization and spatial distribution, with a fixed neighbourhood size to enable meaningful comparisons. Utilizing Geographic Information System and Remote Sensing techniques, the study analysed four domains of urban morphology at the neighbourhood level: education-health-recreation facilities, street patterns, land use diversity, and building density. Principal Component Analysis was employed to reduce the dimensionality of each domain and derive an Environmental Quality Sub-index (EQ-I). This index can be standardized and personalized based on individuals' values and preferences. The EQ-I facilitates both quantitative and qualitative comparisons through visual representations. The study exemplifies a methodological approach to consolidating multiple variables into a single index, considering the differential weighting of preferences. The methodology employs direct and objective measures that can be adapted and replicated in other cities, providing standardized yet personalized scores for regional and international comparisons. The findings present valuable insights for policymakers and urban planners aiming to enhance the environmental quality of ultra-dense urban settings.

ARTICLE HISTORY
Received 8 May 2024
Accepted 5 January 2025

KEYWORDS
Urban morphology; objective measure; environmental quality of life; Geographic Information System

1. Introduction

The concept of Quality of Life (QOL) has attracted growing attention since the 1960s, coinciding with the era of rapid urbanization and globalization (Ma et al. 2020). By 2020, the global urban population had surged to 56.2%, with certain Asian megacities, such as Singapore and Hong Kong, achieving full urbanization (Huang and Xu 2022). Several factors also contribute to the contemporary emphasis on QOL in modern societies. Firstly, the rapid advancement of technologies has significantly impacted the lives of individuals worldwide. Secondly, there has been a notable rise in general income levels. To most people, the pursuit of an enhanced quality of life becomes a priority once basic needs are satisfied. Nevertheless, the task of defining and reaching a consensus on the QOL remains a complex challenge (Appio, Lima, and Paroutis 2019; Cotten 2017; Sawamto et al. 2018).

The QOL encompasses all aspects of life that can be evaluated at both special individual and general population levels. For special individuals, the focus is primarily on personal perceptions and experiences related to their health conditions. Health-related QOL is a central concern for individuals, particularly in the context of traditional diseases such as different kinds of cancer (Chung et al. 2020; Mokhtari-Hessari and Montazeri 2020), inflammatory bowel disease (Knowles et al. 2018), and mental diseases (Akbari and Hossaini 2018; Perotta et al. 2021), which have been extensively studied over the years. Additionally, the COVID-19 pandemic, as one of the most impactful diseases on our lives, has shifted research attention towards the QOL of patients suffering from different COVID-19 symptoms, life under the quarantine has also been the focus of QOL at the individual level (Ferreira et al. 2021; Malik et al. 2022; Poudel et al. 2021).

The QOL of the general population encompasses various aspects of the residents' lives within a spatial area, including social, economic, and environmental aspects (Croes, Ridderstaat, and van Niekerk 2018; Fleming et al. 2016; Ramkissoon 2023; Schalock et al. 2016; Uysal et al. 2016). The social aspect examines the demographic

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This article was originally published with errors, which have now been corrected in the online version. Please see Correction (http://doi.org/10.1080/19475683.2025.2466906)

characteristics of the residents, such as gender, age group, and marital status. Gender is frequently considered when identifying key social indicators that influence QOL (Lee, Xu, and Wu 2020). Among older adults, males generally report a higher QOL than females across different countries, although the associations between QOL and sociodemographic factors, health-related factors, and social support factors vary by country. QOL is also explored separately by age groups from children and adolescents to adults and the elderly. For children and adolescents, QOL is often linked to personal development, whereas for the elderly, it is closely related to physical health conditions (Belsey et al. 2010; Prasad, Fredrick, and Aruna 2021; Ravens-Sieberer et al. 2014). Further demographic characteristics were considered in a study conducted in Southeast Queensland, which utilized a random sample of 1,347 citizens covering various gender groups, employment statuses, education levels, and marriage statuses (Mccrea, Stimson and Western 2005). Similar research on individual satisfaction among married couples, encompassing life satisfaction, depression, work alienation, and marital satisfaction, was conducted in Hong Kong (Cheung 1997; Ng, Yang, and Chiu 2024). These studies found that different demographic characteristics significantly affect residents' perception of QOL. The social aspect also includes normative ideals of a good life, which are based on religious, philosophical, or other systems related to the social sciences (E. Diener and Suh 1997). Key indicators in this context include relationships with others, self-esteem, self-satisfaction, life expectancy at birth, overall crime rate, and population metrics.

The economic aspect of QOL assesses whether citizens can achieve their desires given the resources they possess, using indicators like income, consumption, labour market conditions, and housing market dynamics (Bridge, Adhikari, and Fontenla 2016; McCrea, Shyy, and Stimson 2006). Evidence indicates that national wealth positively impacts QOL, with significant improvements observed as wealth extends to the middle class (E. D. Diener and Diener 1995; Hagerty 1999; Kamp et al. 2003). Economic status, often analysed through income and expenditure, is commonly referred to as the 'standard of living'. Income and employment are critical measures for determining whether an individual's economic situation is improving or deteriorating (Smith David 1973). The availability of satisfactory employment opportunities and the level of economic growth significantly influence job vacancies (Shafer, Lee, and Turner 2000; Ülengin, Ülengin, and Güvenç 2001). Additionally, various allowances and benefits, excluding salary, are important indicators of economic deprivation (Payne and Abel 2012). Conversely, the level of consumption or expenditure on economic activities also reflects an individual's QOL. Relevant indicators include the cost of living and housing affordability, often measured by the percentage of public housing (Ülengin, Ülengin, and Güvenç 2001).

Although QOL is primarily evaluated based on personal perceptions of various aspects of living conditions, the surrounding environment also plays a crucial role. The environmental aspect of QOL has only begun drawing significant attention in recent decades. As the basic needs are increasingly met, awareness of living and working environments has risen (Moen and Yu 2000; Orru et al. 2016; Siu and Xiao 2016). Indicators for environmental QOL have traditionally been limited to certain aspects of natural resources, such as the air (Baklanov, Molina, and Gauss 2016) and water conditions (Wu et al. 2018), which represent only the tip of the iceberg in terms of factors affecting residents' QOL. In 2009, the Chinese University of Hong Kong developed a QOL index for Hong Kong, which includes environmental indicators such as air quality, water quality, noise levels, and the recycling rate of municipal solid waste (Chan et al. 2005). The built environment has garnered increasing attention in recent decades. The transportation network, including public transportation, significantly affects QOL (Kim et al. 2020; R. J. Lee and Sener 2016; Pichardo-Muñiz 2011). Land use patterns, such as the percentage of green spaces versus residential areas, have also been explored (Krekel, Kolbe, and Wüstemann 2016; Schetke, Haase, and Breuste 2010). Recreational facilities, such as parks, have been shown to positively correlate with QOL (Giannico et al. 2021; Parra et al. 2010). The City Development Index (CDI) was created to evaluate urban development levels, also including infrastructure as one of its five domains, alongside waste management, health, education, and city productivity (UN-HABITAT 2002). The fundamental assumption linking environmental sustainability and QOL is that a sustainable society cannot be achieved without sufficiently good environmental quality (Moser 2009; Uzzell and Moser 2006).

QOL can be evaluated through two categories, subjective and objective measurements. In the current literature, subjective indicators are the primary methods (Costanza et al. 2007; Low et al. 2018; Marans 2003; Oyama et al. 2017). It focuses on individuals' perception of various aspects of their life and well-being. Subjective measurements encompass social factors such as self-esteem, self-satisfaction, and interpersonal relationships (Ghartappeh et al. 2020); economic factors such as financial pressures and satisfaction level of income (Tran et al. 2020); and environmental aspects such as satisfaction with air and water conditions (McCrea, Shyy, and Stimson 2006). Interviews, questionnaires, and telephone surveys are the main methods for collecting

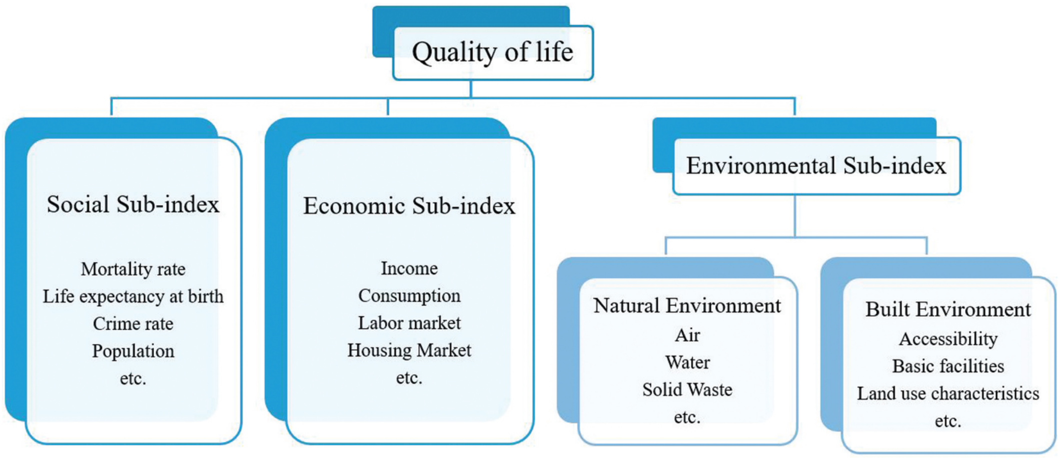

Figure 1. Structure of objective indicators for quality of life (compiled by author).

subjective data. Although the procedures for data collecting and questionnaire analyses are straightforward, conducting subjective measurements on a large scale is time-consuming and expensive. Moreover, the research only relies on the questionnaire results are easily affected by the personal experiences, bias, and characteristics of the surveyed respondents (Cummins 2000). Objective measurements, on the other hand, rely on unbiased data to cover multiple aspects, including social, economic (Croes, Ridderstaat, and van Niekerk 2018), health (Low et al. 2016), and environmental factors (Stimson and Marans 2011). As shown in Figure 1, the QOL in different aspects could be illustrated by using objective indicators. Objective social indicators explored in previous research include mortality rate, life expectancy at birth, overall crime rate, population, and rate of notifiable infectious diseases (Dorling 2004; Santos and Martins 2007; Uysal et al. 2016). Objective economic indicators provide numerical descriptions of the residents' financial status. Environmental QOL can be divided into natural environment indicators, such as air and water quality, and built environment indicators, such as building characteristics and road patterns. Quantified values for QOL are as essential as subjective measurements, as they provide a more objective basis for assessing the quality of various aspects of life.

As explained above, this paper identifies three primary research gaps:

(i) Subjective measurements alone cannot accurately represent the true QOL of a society. Objective measures encompassing social, economic, and environmental aspects should be developed to mitigate individual biases. Comparative studies among different countries could only be achieved through comprehensive measures that include both subjective and objective indicators.

(ii) There is an urgent need for research on the environmental quality of life. Environmental indicators from the natural environment, such as pollution levels, greenery, and built environments, such as connectivity, capacity, and facilities to fulfill daily needs, have been insufficiently explored. The impact of the built environment on QOL remains under-researched. An objective measure of how urban built morphology affects QOL is urgently needed.

(iii) The methodology for integrating multiple objective indicators into a comprehensive index lacks maturity and experience. The process is not yet sufficiently developed to be replicated across different regions for comparative research.

This research focuses on environmental QOL as a demonstration of objective measurements. The first step involved identifying suitable indicators for the built environment that can be measured objectively. Secondly, factual and quantifiable objective measurements were incorporated into the environmental QOL research. These objective measures primarily involve analyses based on satellite imagery and secondary data provided by official governmental departments, such as the census data (Nanor, Poku-Boansi, and Adarkwa 2018). Relative weights were assigned to the objective indicators based on quantitative data to achieve accurate values. By the end of this research, a comprehensive Environmental Quality Sub-index (EQ-I) was developed. The methodology for constructing this index was also demonstrated to inspire other comparative studies involving the integration of multiple indicators into a comprehensive index.

The most significant benefit of this proposed objective measurement is the elimination of biases and survey errors. By employing transparent, impartial, and uniform objective measures, QOL comparisons among different places can be facilitated. The developed methodology can be applied in multi-dimensional research across various settings, enabling cross-comparison.

2. Methodology

This study evaluates the environmental quality of life from built environmental aspects. Hong Kong, a super compact city, was selected as the study area. Geo-spatial data were used to extract the built environmental indicators objectively. Geographic Information System (GIS) was a powerful tool for analysing spatial data. At the end of this chapter, a comprehensive, objective environmental QOL index was developed.

2.1. Study area

Hong Kong Special Administrative Region (HKSAR) I geographically enclosed by the Pearl River Delta and the South China Sea in southern China. Hong Kong's population density is among the mega-cities in the world. Although Hong Kong's territory is about 1,106 km^2 with 7.4 million inhabitants, much of the land is mountainous (Census and Statistics Department of Hong Kong 2021). Moreover, around 440 km^2 of the total area (about 40%) was reserved for country parks (Agriculture, Fisheries and Conservation Department 2017).

The Hong Kong development constraints dictate the compactness and dispersion of its urban form. The characteristics of all the neighbourhoods are significantly different. In this case, one index for the whole city is not representative, while the evaluation in smaller areas is urgent. The geographical units employed by the Hong Kong Government are various for different purposes such as general reference, census, and planning. The most common geographical units for Hong Kong are Hong Kong Island, Kowloon Peninsula, and New Territories (including East and West). The size and degrees of urban development of these regions are different, as shown in Table 1.

This geographical unit of Hong Kong is not adopted because not only is the area too broad, but also, these spatial boundaries are unique in Hong Kong and cannot be generalized for other places. If we want to compare the QOL situation in different cities with different sizes, the QOL index extracted from various study areas will be misleading. So, a fixed study area is necessary. Standardized or fixed areal units of 800 m to 1000 m radius were used in previous research about the environmental characteristics of a neighbourhood (Carver et al. 2010; Lotfi and Koohsari 2009). In this study, the 800 m × 800 m square was defined as the spatial unit. Based upon past research that an individual's common activity space is a 15-minute walking distance, the fixed 800 m × 800 m shall be referred to as the 'neighborhood' (Inoue et al. 2010). Figure 2 illustrates the 89 selected, which are well-spread all over Hong Kong.

2.2. Software and data resources

Geotechnics such as Geographic Information System (GIS) and Remote Sensing (RS) were employed to objectively evaluate the built environment of a neighbourhood. The land cover characteristics in the 89 study neighbourhoods were extracted from digital maps and satellite images (Table 2). Considering the data need to be objective and easily accessible, official statistical data such as census and digital maps from the government were sourced for this research. Hong Kong's data situation is more complete. Suppose the data sources are not already available from the census or in a digital format. In that case, most of the indicators involved in this research could be extracted from satellite imagery.

2.3 Environmental domains

Four domains were selected for a better assessment of the built environment under the environmental sub-index of QOL: education-health-recreation facilities (EHR facilities), street pattern, compatible land use diversity, and building density. All the spatial data can be extracted by using GIS objectively. This ensures cross-

Table 1. Geographical unit of Hong Kong (compiled by author).

Region		Area (km^2)	Urban (km^2)	No. of selected neighbourhood
Hong Kong Island		80.62	18.80	19
Kowloon Peninsula		46.94	25.04	21
New Territories	New Territories East	500.51	53.82	22
	New Territories West	476.34	75.79	27

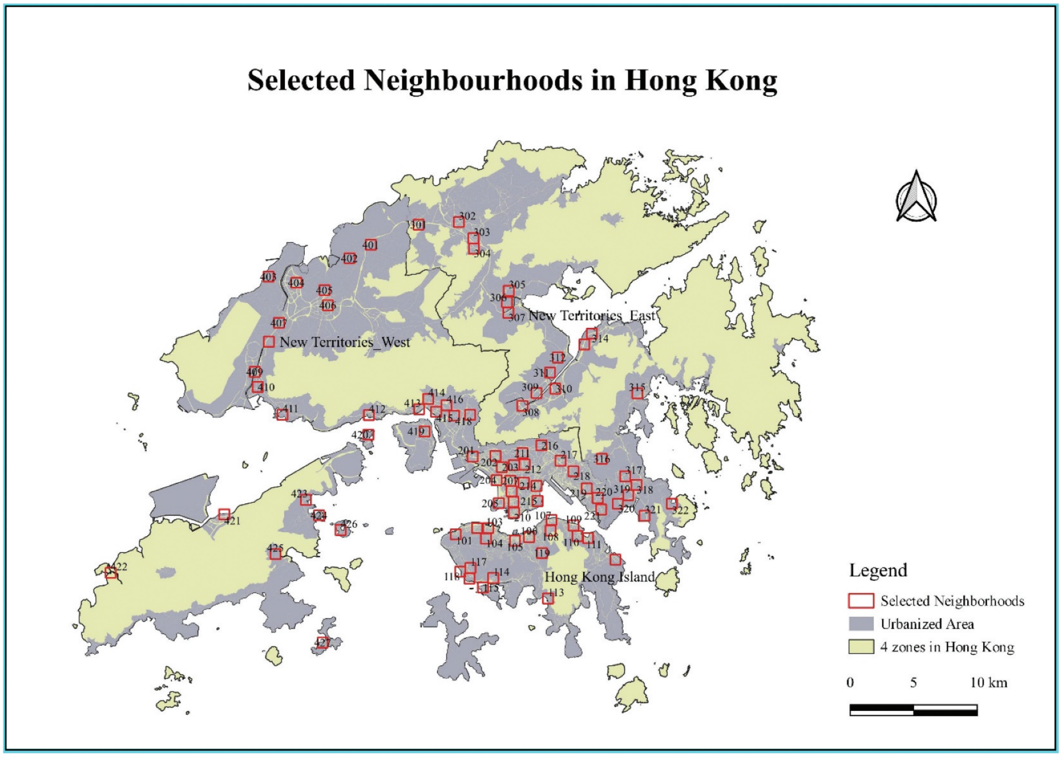

Figure 2. The locations of 89 selected neighbourhoods (numbered according to spatial order)(produced by author).

Table 2. Data resources used in the research (compiled by author).

Dataset		Content
Digital Map	Community Data	Education Facilities Health Facilities Recreation Facilities Sports Facilities
	Road Centreline1000	Road Centerline
	B10000	Road Polygon
	B5000	Sea Polygon Building Footprint
	Outline Zoning Map	Land Use
Satellite Image	SPOT 5	Habitat Map

comparison among different places since the objective indicators are not easily affected by individual opinions and experiences.

All these four domains are closely related to the QOL. Firstly, developing educational, medical, and recreational services is one of the most critical determinants affecting urban environmental quality. The medical (including sanitation) and education services have proved to be the key indicators making the urban and rural areas different in previous research (Gou et al. 2018; Yaya et al. 2017). There are positive effects on the urban quality of life because of the availability of medical, educational, and recreational facilities. The intersect function in GIS computes the number of facilities in the fix-size neighbourhood box (800 m × 800 m).

Secondly, the convenient level of transportation in a given environment could be indicated by the road pattern, such as the road density and intersection. As shown in Figure 3, the road pattern in Hong Kong is diverse. The road density in Mong Kok (Figure 3(a)) is denser compared to Tseung Kwan O (Figure 3(c)). Moreover, the number of road intersections in Mong Kok (Figure 3(b)) is much higher than in Tseung Kwan O (Figure 3(d)). Road network development is not only considered as a basic condition for economic growth but also a prerequisite for social development (Rokicki and Stępniak 2018). Moreover, road safety will be significantly affected by street network characteristics. Previous studies have proved that the street pattern with lower density may cause a higher chance of fatal vehicle crashes (Marshall and Garrick 2011; Zhang et al. 2015). Both

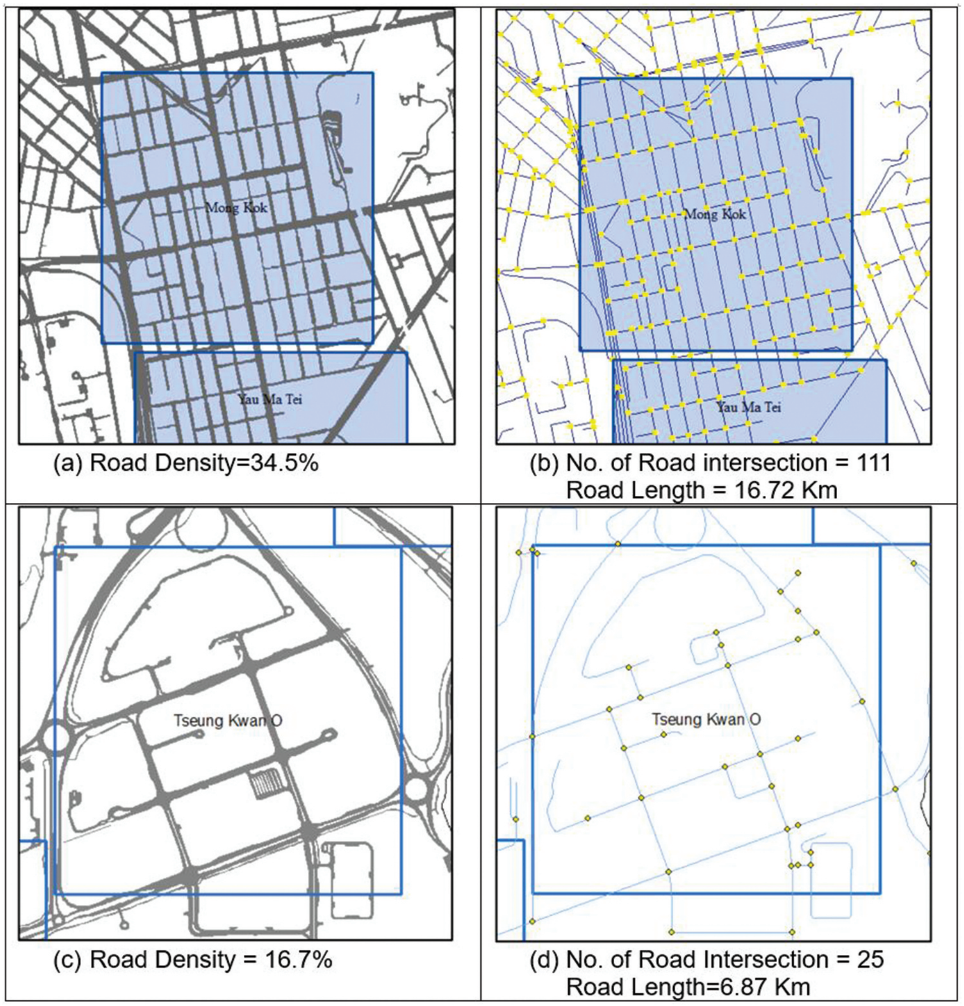

Figure 3. The examples of road density and road intersection in the selected neighbourhoods (a,b: Mong Kok; c, d: Tseung Kwan O) (produced by author).

the local road surface area and the number of intersections were studied in this research.

Thirdly, the land use pattern is diverse in Hong Kong (Figure 4). The people's will to engage in walking rather than other traffic media is linked to a higher degree of land use diversity. Since industrial lands may cause poor air quality or a higher crime rate, industrial land use was excluded from the compatible land use mix index (Lai et al. 2018; Sypion-Dutkowska and Leitner 2017; Xu et al. 2016). Finally, the footprint intensity was also calculated to show the compact level in the neighbourhood. The clear indicator within each domain is shown in Table 3.

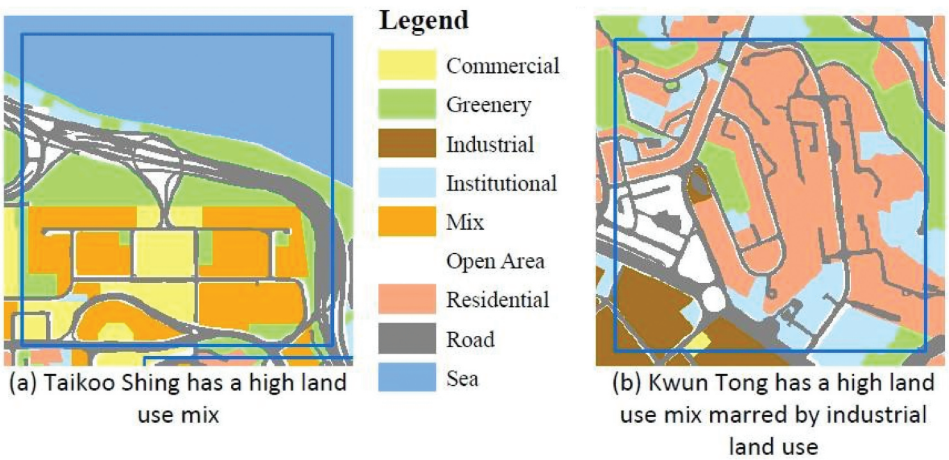

Figure 4. The land use patterns (produced by author).

Table 3. Selected indicators for each domain (produced by author).

Domain	Indicator
Education-Health-Recreation Facilities	• Educational Facilities *Kindergartens, government involved primary/secondary schools, private primary/secondary schools, international primary/secondary schools and higher education institutions)* • Medical Facilities *Clinics and hospitals* • Recreational Facilities *Beaches, children's playrooms, holiday camps, parks, and zoos* • Sports Facilities *Badminton, basketball, tennis, indoor fitness rooms, etc.*
Local Street Network	• Road Density *The percentage of the total road surface out of the total land area excluding sea area; road surface includes all of the main roads, secondary roads, flyovers, tracks and bicycle tracks except expressways* • *Number of intersections of local roads* • Toal length of local roads • Intersection per length of local roads
Compatible Land Use Diversity	• Commercial • Greenery • Institutional • Open Area • Residential *Note:* *Industrial land use is not involved in this study because of incompatibility with other land use types*
Building Footprint Intensity	Proportion of land area covered by building footprints

3. Results and discussion

After extracting the spatial information using geo-technology, such as remote sensing and geographic information system, the model for deriving the Environmental Quality Sub-index (EQ-I) was built. Visualization was also achieved by using different methods, such as radar charts and maps.

3.1. Environmental quality sub-index

The biggest challenge of this research is how to manage the difficulties of interpreting domains or components of multidimensional environmental quality.

Figure 5 describes the basic processing steps of the measurement process based on statistical methods for variable reduction. Various indicators from the Environmental domain, including education-health-recreation facilities (EHR), local street network, compatible land use density, and building footprint intensity, were involved. Production to reduce the complexity of the indicators is illustrated in Figure 5.

As seen from the above figure, the first step is reducing the number of indicators covered by each domain. The statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS). Principal component analysis (PCA) and indexing methods (e.g. compatible land use mix index) were employed to achieve the goals. Figure 6 shows an example of the EHR service index. The final factor score for the EHR service will be calculated using the component matrix as the weights. In this example, 57.9% of the variances for the EHR domain were explained by principal component 1. The weighting of each indicator was provided from PCA, which is 0.763, 0.720, 0.760, and 0.8 for education, clinics, physical facilities, and recreation separately. The principal component score will consider the matrix within the component. This method reduced the indicators in each domain to a single score. This step could be repeated in the domain of road networks to achieve the principal component score of the principal component factor standing for the most significant proportion.

The land use mix index is a well-established index, while the 'compatible land use diversity' domain is advised based on it by excluding the industrial land use type. Industrial land use is correlated with poor air quality and a high crime rate (Adebiyi 2022; Browning et al. 2010). In this case, the compatible land use diversity is more suitable to represent QOL than general land use diversity. The building density is a 2D indicator that is straightforward, which is no need for further reduction. Similar indicators in 3-dimensional indicators, such as building volume and well-defined index such as sky view factor, could also be used to represent the city's compactness. Since the value for building density will be explained as lower density means less compact and better environmental quality, the values of building density must be inverted to coincide with higher values equal to better quality as the other indicators do.

Four sets of domain scores, EHR facility, local street pattern, compatible land use diversity, and building density, were extracted at the end of this step. Cluster analysis would be employed after this process to analyse each category's characteristics better. The characteristics could also be used to check the validation of the ranking

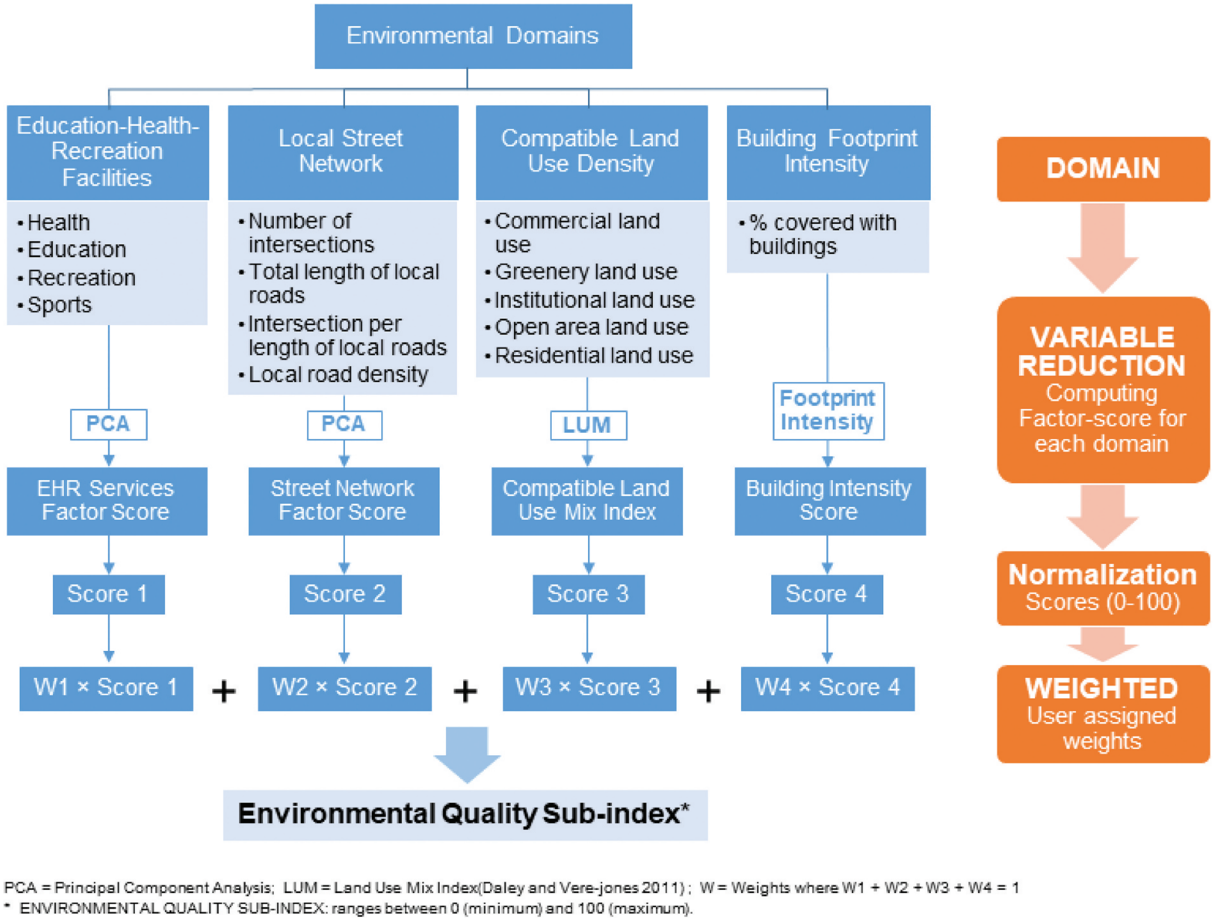

Figure 5. Procedures and statistical techniques for deriving the environmental quality sub-index (produced by author).

Component Matrix[a]

	Component
	1
education	.763
clinics	.720
physical	.760
recreation	.800

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.318	57.945	57.945	2.318	57.945	57.945
2	.647	16.177	74.122			
3	.561	14.024	88.145			
4	.474	11.855	100.000			

Extraction Method: Principal Component Analysis.

$F1 = \text{Education} \times 0.763 + \text{Clinics} \times 0.720 + \text{Physical} \times 0.760 + \text{Recreation} \times 0.800$

$\text{Education-Health-Recreation Services domain factor score} = 0.579 \times F1$

Figure 6. The calculation of EHR domain score (produced by author).

based on the actual situation of the neighbourhood. The normalized domain factor scores from step two range from 0 to 100. Normalization ensures that all variables contribute equally to a scale when combined. To yield a comprehensive Environmental Quality sub-index (EQ-I), the normalized domain scores will be added up in step three. A weighted score of the individual perspective could be added to adjust the relative contribution. One person's point of view on these domains will be applied in different places. This methodology ensures meaningful comparison across other times and spaces.

The four environmental domains can be reduced to a single uniform ranking; the following equation below can be used to obtain an overall index as the EQ-I for each neighbourhood.

Environmental Quality Sub-index = Weighting 1 × Education-Health-Recreation Score

+ Weighting 2 × Local Street Network Score
+ Weighting 3 × Compatible Land Use Diversity Index
+ Weighting 4 × Building Footprint Intensity Score

Where Weighting 1 + Weighting 2 + Weighting 3 + Weighting 4 = 1

Although the weightings for the four selected environmental domains could be different, this research used equal weighting to illustrate the possible results. The EQ-I for each neighbourhood is calculated. As you can notice, the EQ-I's minimum and maximum values are 0 and 100. Under this theory, greater values imply better environmental quality. This index could evaluate the environmental performance of the neighbourhoods more comprehensively. Compared with the scores for the performance of specific aspects in a neighbourhood, such as air quality, building density, the number of facilities exits, etc., the residents will have a more precise opinion of the overall situation. For example, Mong Kok is a typical location with many education facilities, clinical facilities, and high accessibility. However, the land use design and the greenery area are relatively poor. In this way, when the residents choose the optimal living location, they can also evaluate all the potential choices comprehensively based on their own opinions.

3.2. Spatial pattern in Hong Kong

The quantitative domain sub-scores and EQ-I extracted through the above steps could be illustrated in plenty of methods, such as text explanation, tabular statistical overview, and graphic illustration. Although the text explanation and tabular formats often perform excellently, there are still difficulties in providing an overview of results and comparative analysis (Saary 2008).

The graphical representation that could be used for single and multiple variables patterns has become a commonly accepted illustration method. The radar chart is a graphical representation method helpful for visual analysis and quantitative comparisons of multi-dimensional variables by shapes (Chang et al. 2012; Kalonia et al. 2013; Li et al. 2006). The radar chart was employed to show the different characteristics of the four geographical units in Hong Kong (Figure 7). Due

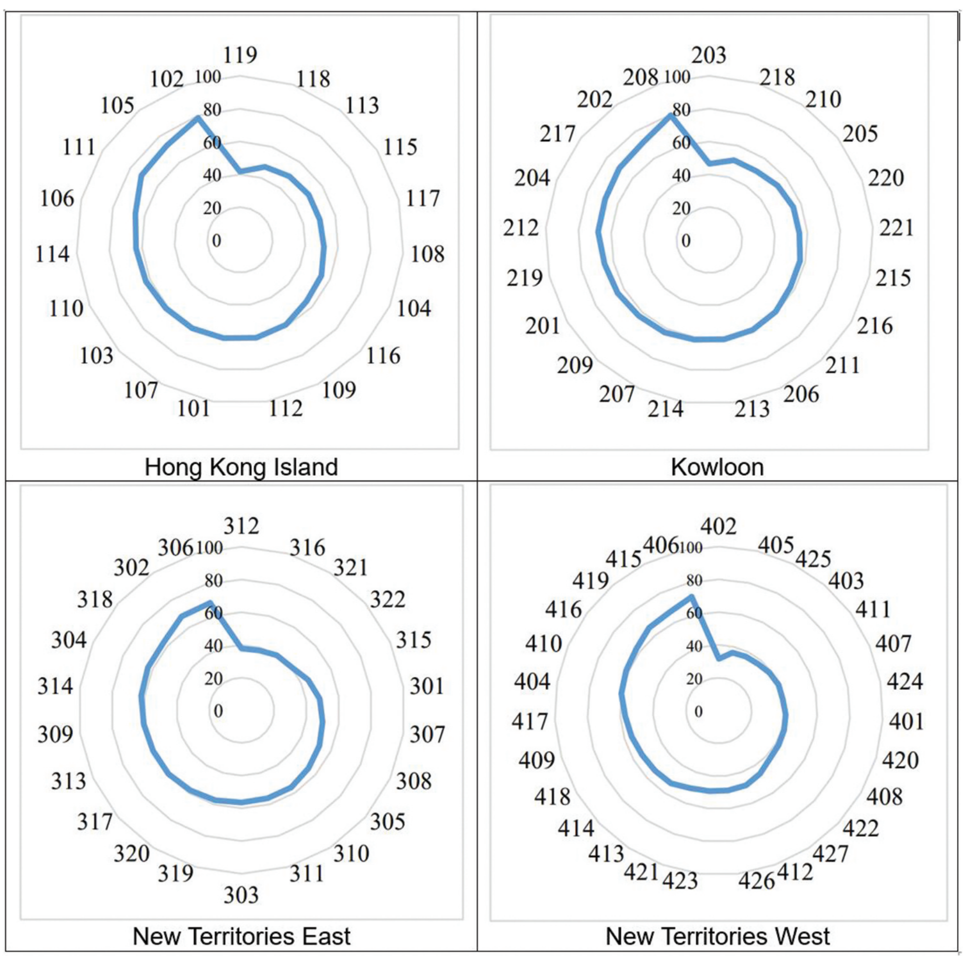

Figure 7. Environmental quality sub-index by four geographical units of Hong Kong (produced by author).

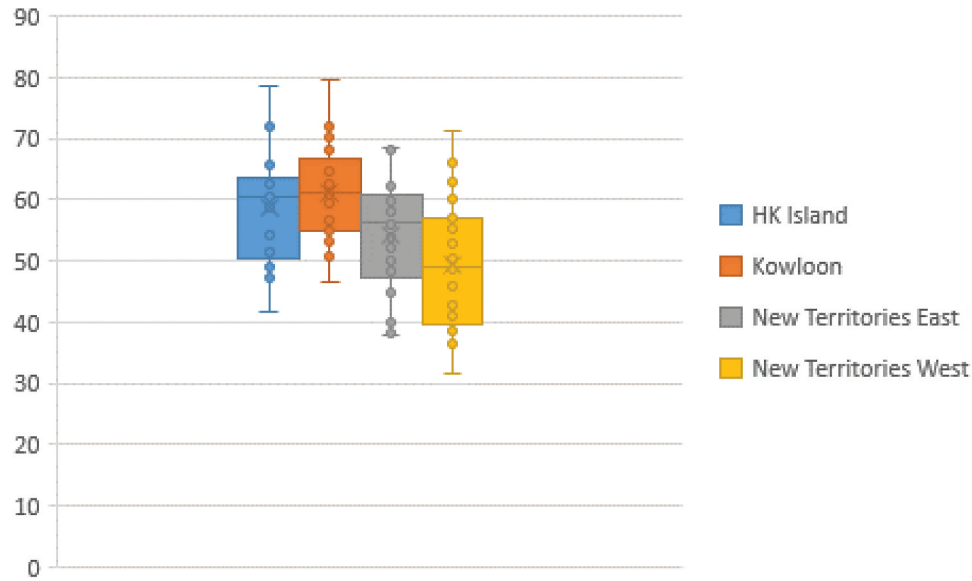

Figure 8. The EQ-I for four geographical units of Hong Kong (produced by author).

to the unique appearance of the radar chart, it is also known as a spider chart, web chart, or start chart (Komaladewi et al. 2019). The number of vertices along the outer edge of a radar map or its diameter varies depending on the number of cases or members observed. To be more effective, the axes of the radar chart from the centre point of the graph should have numerical values which are easy to interpret (such as increasing values like a percentage). Then each vertex is plotted along the corresponding axis based on the quantity observed. Vertices arrangement may follow any desired sequential order that will likely result in a spiky-looking radar table. A radar map (or one of the multiple radar charts) may have the observed quantity sorted in ascending order before plotting for easy visualization and comparison. This modification will delete a radar chart's spikiness to produce a smooth polygon.

As seen in Figure 7, the polygon size may indicate the performance of one variable in a group. This research divided 89 neighbourhoods into four geographic regions (i.e. Hong Kong Island, Kowloon, New Territories East, and New Territories West). A radar chart for the EQ-I can be drawn for each geographic region to examine regional environmental differences by comparing the polygon size and shapes. The box chart shows the general distribution for these four geographic regions (Figure 8). The EQ-I in Hong Kong Island and Kowloon are generally higher than in the New Territories. The highest EQ-I appeared in Kowloon (Yau Ma Tei), which has well-established facilities nearby. At the same time, the greenery is not as compact as the old centre of Yau Ma Tei, followed by the Sai Ying Pun, located on Hong Kong island. The lowest EQ-I appeared in Fairview Park (New Territories West), a neighbourhood consisting mainly of residential land use. The convenience level of this neighbourhood is relatively low. However, the buildings in this neighbourhood are only three floors, which is not high-rise. A 3D indicator such as building density and sky view factor may be more suitable to be involved. As Hong Kong Island and Kowloon are more highly developed than New Territories, the EHR facilities, the road system, and the mixed land use have better performance than the latter regions. However, the general situation of greenery and compactness in the New Territories is relatively better than in the former areas. The weighting could be applied to modify the neighbourhoods' perceptions based on individual perceptions of the relative importance of the domain involved in EQ-I.

4. Conclusion

This research has pointed to a different angle to evaluate the QOL objectively and proposed a novel method for assessing the built environment on a suitable spatial scale. The necessity of assessments on QOL from more minor levels, such as neighbourhood, is obvious. This methodology could collapse multi-dimensional indicators into a single aggregated index, easing the comparison and interpretation. It also encourages using graphic illustrations such as radar charts, the results easily visualized and compared.

There will be limitations and restrictions at any methodological attempt. Firstly, data availability is always the first concern for objective measures. Although the classification for land use could be extracted from satellite imagery, local knowledge, and on-site verification would still be needed for many developing countries. Secondly, the optimal spatial unit of a neighbourhood hasn't been proved. Different spatial units such as 500 × 500 m, 800 m *800 m, and 1000 m *1000 m have been found in previous literature, while this research employed 800 × 800 m based on Hong Kong's actual situation. Other spatial sizes, such as 200 metres, 400 metres, and 1-kilometre buffer zone, should be examined to explore the optimal spatial units for environmental quality research. The third limitation is the choice of domains for the computation of the EQ-I. The selected built environmental indicators could be involved in the equation, as some other natural environmental indicators, e.g. air quality and recycling rate. Moreover, only two-dimensional mapped surfaces were involved in this research. The three-dimensional indicators (such as sky view factor and building volume) could also be involved in further studies (Chen et al. 2012; Middel et al. 2018; Stephan and Athanassiadis 2017; Zhao et al. 2017). However, this methodology could still be applied in the situation with more indicators. The final limitation is the missing interpretation for optimal thresholds in sustainable development. The standardized scores were adopted in this research while there should be ideal quantities of facilities in a neighbourhood in practice. The thresholds could be explored in both scientific ways and subjective evaluations. Although this research focuses on measuring the environmental quality of life by offering a method to solve multidimensional aspects of it, the overall QOL should involve subjective and objective assessments. The choice of appropriate measures to better inform QOL should be systematic and selective simultaneously.

Despite the limitations elaborated above, the foundation and methodological constructs were proposed in this research for future studies about the objective measurement of QOL, which could avoid extensive workforce and time resources. This research was conducted at the 'neighbourhood' level instead of the 'city', which is more meaningful for comparison of environmental quality.

Declarations

All the sections in this manuscript have not involved humans and/or animals. All authors have no financial or non-financial interests, and study-specific approval by the appropriate ethics committee for research.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Hong Kong Polytechnic University.

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