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URBAN QUALITY OF LIFE EVALUATION USING LAND PRICE WITH STATUS-QUALITY TRADE-OFF THEORY AND ECOSYSTEM SERVICES

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Abstract. Urban Quality of Life (UQoL) is the main objective of sustainable development in the urban context. It is now widely recognised as a multidimensional concept. The satisfaction provided by the elements related to accommodation, such as housing and land, greatly contributes to the satisfaction with quality of life. Meanwhile, the UQoL also contributes to housing and land prices in cities. Our review shows that most current studies on this interrelationship are limited to several dimensions of UQoL and their impact on housing or land prices. This article will fill the gap by using the land price as an input for calculating a UQoL index from the viewpoint of the Status-Quality Trade-Off theory and ecosystem services. A case study was conducted in Cau Giay District, Hanoi, Vietnam, to create a map of the UQoL index and investigate the interrelationship UQoL – land price. In an ideal condition, this interrelationship should be positive (high/low UQoL index – high/low land price). However, this research revealed two other negative scenarios: "high UQoL index – low land price", and "low UQoL index – high land price". These negative scenarios can bring many business opportunities and therefore be interesting for stakeholders in the real estate market.

Keywords: urban quality of life, land price, interrelationship scenarios, Status-Quality Trade-Off theory, ecosystem services, space syntax, geographic information system.

Introduction

Urban Quality of Life (UQoL) is widely recognised as a multidimensional concept. Din et al. (2013) defined the term of UQoL as referring to "the urban planning which has the objective to realise the sustainability of the development with respect to an individual's quality of life" (Din et al., 2013). The authors have identified seven dimensions of the UQoL: environmental, physical, mobility, social, psychological, economic, and political. Each dimension is described by a number of indicators, which may be logically grouped into several sub-dimensions. Until now, many researchers have attempted to measure and analyse UQoL through indicators using one of two approaches: 1) the objective approach, based on analysis of secondary data, such as those derived from official statistical collections, for example, the census; or 2) the subjective approach, based on primary data collected through sample surveys in which people's perceptions of quality of life domains are measured on scaled attributes (Marans & Stimson, 2011). Recently, some efforts have been made to integrate both approaches (Garau & Pavan, 2018; Malkina-Pykh & Pykh, 2008). A related concept to UQoL is the subjective well-being, which refers to individuals' evaluation of the quality of their lives in general, including pleasant or unpleasant affects, and life satisfaction (Diener, 1994). Life satisfaction judgements are functions of different domain satisfaction judgements, including housing satisfaction. Many studies have shown that physical conditions of housing, housing tenure, and social status have influence on the subjective well-being (Clapham et al., 2017). In addition, many indicators of the UQoL, such as the air quality (Chattopadhyay, 1999; Komarova, 2009), the river pollution (Chen, 2017), and the urban green space (Panduro & Veie, 2013), have been analysed using the hedonic model based on housing prices. Some indicators related to urban spatial structure, as well as accessibility to urban amenities, have been analysed by Space Syntax and Geographic Information System (GIS) through housing and land prices (Le et al., 2019; Liu et al., 2015; Morales et al., 2019). The housing price is

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one of the key indicators that reflect the level of economic development of cities and the quality of life (Burinskienė et al., 2011). Housing is the base and most detailed level of satisfaction on the UQoL geographic scale (housing, neighbourhood, community, and region levels of satisfaction) (Marans & Stimson, 2011). Some studies on the housing market in Vietnam have also shown that housing price determinants can be related to urbanisation and its management by the government, and externalities (for example, accessibility and proximity to urban amenities, infrastructure, air quality, traffic congestion, etc.) (Chung et al., 2018; Kato & Nguyen, 2009). In Hanoi, the Capital of Vietnam, the price of property in the Ancient Quarter is extremely high, although this zone has poor living conditions (Kato & Nguyen, 2009). In order to explain this situation, it may be necessary to consider other factors related to social and business aspects, lifestyle, etc. (Hoang & Nishimura, 1990).

When making a decision to buy a land parcel or a house, a purchaser typically takes into account a number of factors. According to the Status-Quality Trade-Off (SQTO) theory, the housing value for any social group consists of two components: the housing status and the dwelling quality. "Housing status is a measure of the social desirability attached to housing in a particular locality, often expressed in non-physical attributes, which are accepted by certain social groups. Dwelling quality embodies the physical, measurable elements that constitute the basis for the normal use of a dwelling" (Hoang & Wakely, 2000). It seems that the SQTO theory is increasingly becoming an applicable theoretical construct in the field of residential choices within urban studies (Cosacov, 2019; Davoudi et al., 2009), as well as housing price index estimation (Alexis et al., 2016; Bui et al., 2017). Although residential choices occur at the household level, in explaining residential choices, researchers have shown the influence of not only micro-level but also macro-level factors like housing policies, economic situation, and the environment (Cosacov, 2019). While house and land are parts of an accommodation, in large cities, the land part often accounts for a much greater value than the house part. In this study, the SQTO is applied to urban residential land in the sense that the land value includes two components: status and quality.

In ecology, an urban area is considered as an ecosystem with four main components: the biotic complex, the physical complex, the built complex, and the social complex (Pickett & Grove, 2009). Urban ecosystems can bring benefits to people through ecosystem services. According to the Common International Classification of Ecosystem Services (CICES) V5.1, ecosystem services can be categorised into three main types, namely: provisioning; regulating and maintenance; and cultural services (Haines-Young & Potschin, 2018). The potential availability of the urban ecosystem services provided by the land use is mainly related to cultural services and a small part of regulatory services. However, the demand for the provisioning, regulation, and maintenance services is huge in reality, due to the high population density and intensive human activities in the cities (Burkhard et al., 2014).

From our point of view, the issues related to urban areas, such as the status and quality of dwelling, the ecosystem services, are all of great concern to the quality of human life. Therefore, these issues can directly or indirectly affect the value of land parcels, where daily human activities occur. In an assumption of the existence of an interrelationship between UQoL and land price, most reviewed studies are limited to several dimensions of the UQoL and their impact on housing or land price (i.e., one-way relationship) (Crompton, 2001; Kim & Goldsmith, 2009; Kohlhase, 1991; Liebelt et al., 2018; Morales et al., 2019). This research will partly fill the gap by using the land price as input for calculating the UQoL index from the viewpoint of SQTO and ecosystem services. This combined approach represents a comprehensive and continuous analysis of UQoL that can range from the parcel level to the regional level, demonstrating a combination of objective and subjective approaches. Because SQTO is a new look at the dynamics of urban residential areas, based on the relationship between the housing status and the dwelling quality, this approach helps to assess UQoL at each time point in the urban development process. Obviously, the analysis of UQoL not only allows to measure individuals' well-being, but also has broader implications for research on urban policy and sustainable development in general. After that, the scenarios of interrelationship between the UQoL index and the land price will be investigated.

This article is organised as follows: the first section introduces the study area and data, followed by a workflow for calculating the UQoL index; the second section shows the results of calculation of the UQoL index in Cau Giay District, Hanoi City, Vietnam; the third section discusses about the distribution of the UQoL index in Cau Giay District, four interrelationship scenarios between land price and the UQoL index, application of the UQoL index, and further research orientation; and the final section makes concluding remarks.

1. Materials and methods

1.1. Study area and data

Cau Giay District, Hanoi City was selected as the study area of this research. It is among the most well-developed districts in Hanoi and still has a good development potential. Geographically, Cau Giay is the hub connecting the city's centre with developing outskirt areas in the west. The district consists of eight wards and is the location of several new urban blocks, such as Trung Hoa – Nhan Chinh, Dich Vong, etc. (Figure 4). Furthermore, with numerous green parks, pagodas, and urban amenities, Cau Giay is a newly developed area of Hanoi that attracts a lot of people to live in. However, in addition to these favourable factors, the district still faces significant problems in the development process, such as environmental pollution, pressure on land use, and the lack of synchronised urban planning. As in other urban areas of Vietnam, a popular type of land use in Cau Giay is the mixed use of residential land for both living and small business (such as retail or service, etc.). Therefore, the factors related to business suitability and profitability are very important in the formation of the urban residential land price.

To investigate how the land price reflects the UQoL index, we collected cadastral maps and land price survey data in the district and surrounding areas. Spatial data, such as the street network and urban facilities (schools, hospitals, pagodas, etc.), were extracted from the cadastral maps. Attributive data was obtained from both field surveys and spatial analyses. The field survey data consist of 427 real estate transactions from 2017 to 2019 with various information about land parcels, houses, land owners, water and electricity utilities, security environment, drainage services, etc. The survey was carried out over three periods: 1) December 2017 – March 2018; 2) January 2019 – April 2019; and 3) July 2019 – October 2019. The land price information was collected mainly from householders (land owners, renters, or family members) through interviews. Common prices from third parties (e.g., real estate agents) were also collected and serve as a base for screening out abnormal land prices. To ensure consistency in time, the collected land prices are corrected to the price level of the fourth quarter of 2019 using data from the report on quarter property price index for residential land in Hanoi City published by Savills company (Savills, 2020). The data were then passed to two real estate experts to verify their accuracy. In addition to the data collected directly, some data related to the UQoL indicators were extracted or calculated using GIS and Space Syntax techniques. All data were integrated and stored in an ESRI's ArcGIS® geodatabase.

Data of 32 air and 24 water quality monitoring stations were obtained from the Report of Environmental Protection Works of Cau Giay District in 2018 (Department of Natural Resources and Environment of Cau Giay District, 2018). According to the Report on the State of Vietnam's Environment for the period 2016–2020, the air and water pollution in Hanoi City increased during this period, but only gradually (Vietnam Ministry of Natural Resources and Environment, 2021). Based on this fact, and due to difficulties in collecting environmental monitoring data in 2017 and 2019, we used only the data in 2018 with the assumption that the air and water quality parameters in Cau Giay District had not changed significantly from 2017 to 2019.

1.2. Method for calculating UQoL index

In this research, we developed a workflow for calculating the UQoL index based on urban residential land prices, as shown in Figure 1. The workflow consists of three phases, which are described as follows:

Phase 1: Field survey

This phase aims to collect information via questionnaires about residential land parcels sold on the market. There are four groups of a total of 46 questions: land owner

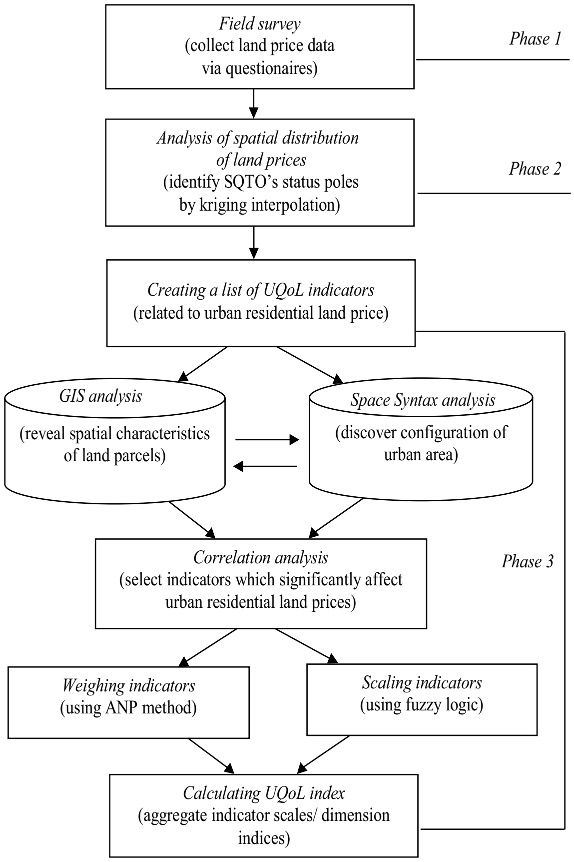


Figure 1. Workflow for calculating UQoL index

information (occupation, number of family members, incomes, etc.); land parcel and transaction information (location, area, shape, transfer price, date of transaction, etc.); house information (house type, number of floors, house price, etc.); neighbourhood characteristics (water and electricity utilities, security environment, accessibility, etc.). The sampling of land transactions is carried out along streets and surrounding areas under normal trading conditions (e.g., excluding transactions within a family, or under forced conditions). The sample locations are indicated on cadastral maps to verify their accuracy and to manage a good distribution over the study area. The minimum required number of samples (N) is estimated as $N > 50 + 8m$ where m is the number of predictors (Green, 1991). The samples are screened for outdated transactions or abnormal prices. House prices, if any, are excluded from the land prices by traditional land valuation methods, such as income analysis, cost analysis. The land prices are normalised in local currency of million VND per square metre and are stored as a point feature class in the ArcGIS's geodatabase.

Phase 2: Analysis of spatial distribution of land prices

The SQTO theory suggests that the urban residential location follows certain organising regularities expressed in the concentric rings around the status poles. These status

Table 1. List of selected UQoL indicators that affect residential land price

UQoL dimensions	Indicators (with ID in parentheses)	Description	Evaluation method | source of data
Environmental dimension	(1) Particles	Mass concentration of particulate matter (PM) in the air (μg/m^3)	ArcGIS's IDW interpolation | official reports
	(2) Noise	Average traffic noise (dBA)	
	(3) GreenDensity	Ratio of the area of water surface, trees, squares to the total area of each ward	ArcGIS's Statistics | cadastral maps
	(4) GreenView	Visibility of a green landscape (0: no, 1: yes)	ArcGIS's Select by location | cadastral maps
	(5) Pollution	Distance from a land parcel to the closest source of air pollution	ArcGIS's Network analyst | cadastral maps, official reports, field survey data
	(6) Drainage	Condition of the drainage system during rains (0: poor, 1: good)	ArcGIS's Field calculator | field survey data
Physical dimension	(7) RankingStreet	The State's ranking of streets (1: high, 2: medium, 3: low)	ArcGIS's Field calculator | State's regulations
	(8) Area	Area of land parcels (m^2)	ArcGIS's Statistics | cadastral maps
	(9) Shape	Shape of land parcels (1: rectangle, square; 2: trapezium, 3: others)	
	(10) Frontage	Frontage of land parcels (m)	
	(11) Depth	Depth of land parcels (m)	
Mobility dimension	(12) Integration_global	Integration value of the whole street network	Space Syntax | cadastral maps
	(13) Integration_local	Integration value on the scale of pedestrian movement	
	(14) Choice_global	Choice value of the whole street network	
	(15) Choice_local	Choice value on the scale of pedestrian movement	
	(16) Connectivity	Connectivity value	
	(17) BusStop, (18) Park, (19) Market, (20) School, (21) UrbanBlock, (22) MainStreet	Distance from a land parcel to the closest bus stop, park, market, school, new urban block, and main street, respectively (m)	ArcGIS's Network analyst | cadastral maps
Social dimension	(23) ComHouse, (24) Administrative, (25) Police, (26) Recreation	Distance from a land parcel to the closest community activities house, administrative office (People's Committee), police station, and recreation site, respectively (m)	ArcGIS's Network analyst | cadastral maps
Psychological dimension	(27) Religion, (28) HistoricalSite, (29) Cemetery	Distance from a land parcel to the closest religious facility, historical site, and cemetery, respectively (m)	ArcGIS's Network analyst | cadastral maps
Economic dimension	(30) Hospital, (31) TransStation, (32) University	Distance from a land parcel to the closest hospital, public transport station, and university respectively (m). The less distance, the more favourable conditions for doing small business	ArcGIS's Network analyst | cadastral maps
	(33) Location	Relative position of a parcel to streets according to the current State's regulation: 1: the land parcel is adjacent to streets 2, 3, 4: the land parcel is adjacent to the branches of the streets with >3.5 m, 2.0–3.5 m, and <2.0 m width respectively	ArcGIS's Select by location | cadastral maps
	(34) BusinessZone	Convenient areas for business (offices, crowded areas, street food areas, etc.) (0: no, 1: yes)	ArcGIS's Field calculator | field survey data

poles represent the highest points of certain kinds of social status, recognised by a given proportion of the population (Hoang & Wakely, 2000). The purpose of this phase is to identify the status poles based on the distribution of land prices in the study area. An applicable tool is GIS's kriging interpolation (Bui et al., 2017). Kriging is considered as the optimal interpolator for spatial variation of the property in terms of the variogram, as it minimises the prediction errors (Oliver & Webster, 1990).

Phase 3: Assessment of UQoL index for each land parcel

The purpose of this phase is to evaluate the UQoL indicators based on land prices. The obtained results are then aggregated to derive the UQoL index. In fact, several steps are involved in this phase: 1) Establishing a list of indicators related to the urban residential land price; 2) Evaluating indicators; 3) Selecting indicators that have high correlation with land price; 4) Weighing and scaling the selected indicators; and 5) Aggregating indicators' scales into composite UQoL index.

Among the seven dimensions described in (Din et al., 2013), six dimensions were considered in this research: environmental, physical, mobility, social, psychological, and economic dimensions. The political dimension was omitted because it does not vary much in the small study area. The indicators' identification criteria for the study area are based on the principles of UQoL introduced by Din et al. (2013) with some adaptations.

The identified indicators (Table 1) are evaluated mostly by GIS and Space Syntax analysis. In this research, the ArcGIS® analysis tools (Network Analyst, Interpolation, Select by Location, etc.) were used to identify the spatial characteristics of the land parcels, such as location, shape, area, accessibility to urban services and facilities, and air quality. Space Syntax, developed by Hillier and Hanson in the 1970s, is a method for analysing patterns of architectural space at both the building and urban levels. It attempts to explain human behaviours and social activities from a spatial configuration point of view (Hillier, 2007). In this research, a Space Syntax analysis was carried out to identify the urban configuration through the street network. The following three Space Syntax's key measures were used:

- *Connectivity* is the local state measure for each line, which shows how many other lines are only one step away from it (i.e. immediately connected to it) (Hillier et al., 1987).
- *Integration* is the global state measure for each line, which is essentially how many other lines are up to *n* steps away from it (Hillier et al., 1987). This measure is based on the term "depth", which calculates the number of spaces and changes needed to reach all other spaces in the system (Berhie & Haq, 2017). Integrated urban spaces with high integration value are expected to attract more movement than segregated spaces with low integration value.
- *Choice* is the global dynamic measure: the degree of choice that each space represents (how likely it is to be passed through) on all shortest routes from every space to all other spaces in the system (Hillier et al., 1987). In other words, it measures how much movement is likely to pass through a space on trips between origin and destination spaces (Berhie & Haq, 2017).

The above three measures can be evaluated on the scale of pedestrian movement or on the whole system by using the DepthmapX open-source software. Some studies suggested that five, ten, or fifteen minutes of walk (equivalent to the distance of 400, 800, and 1200 m respectively) are comfortable walking times to reach services and facilities (Klimanova & Illarionova, 2020). This research used an average value of 800 m to perform the analysis on the pedestrian movement scale.

Among the indicators shown in Table 1, some have a major impact while the others have a minor impact on land prices within the study area. The latter were filtered out by correlation analysis in this research. Pearson's correlation (r) was used to measure the strength of the relationship between two numerically measured variables X (an indicator) and Y (the land price). The absolute values of r range from 0 to 1, where a higher value indicates a stronger relation of indicator X to the land price, and vice versa. Indicators with reliability greater than or equal to 95% (equivalent to significant value less than 5%) are selected. Another task of the correlation analysis is to determine the relationship between indicators. The result of the correlation analysis also serves as an input for weighing the indicators in the next step.

Although indicator values can be presented individually, it is better to mathematically aggregate them into a composite UQoL index to represent an overall picture of UQoL. Aggregation requires weighing and scaling of each indicator (Malkina-Pykh & Pykh, 2008).

The main approach used in many studies for weighing indicators is based on expert opinions, such as Delphi techniques, multi-criteria analysis, or public opinion polls (Malkina-Pykh & Pykh, 2008). In this research, derived from the fact that the indicators can be related to each other, we use a multi-criteria analysis method, namely the Analytic Network Process (ANP), to determine their weights (Saaty, 2006). The outline of the ANP steps in the SuperDecision® software is shown in Figure 2.

In Figure 2, the clusters are the UQoL dimensions and the nodes are the indicators in each dimension. Details on how to compute the super matrices can be found in (Saaty, 2006).

Scaling the indicators is to convert the values of all indicators within each dimension into a unified scale of 0.0 to 1.0. This research used the most popular method, fuzzy logic, which was explained in detail in (Bagnoli &

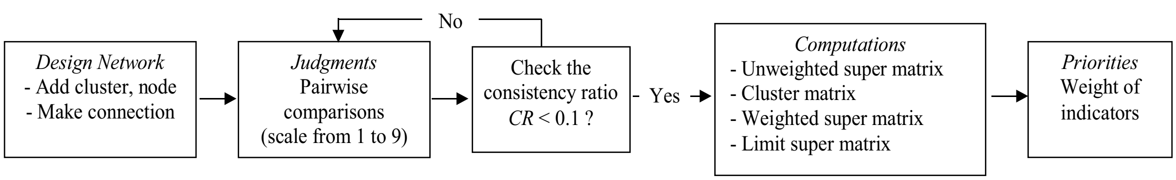


Figure 2. Outline of ANP steps to compute weights of indicators

Smith, 1998). The scaling strategy is different for the three groups of indicators:

– Group of numerical (distance) indicators: Typically, these indicators are positive, i.e., the higher the accessibility is (defined by distance from the land parcel to the closest facilities), the better the scaling is (positive case). However, some indicators, such as *Pollution* and *Cemeteries*, have the opposite scaling and are called negative. Figure 3 shows graphs of membership functions for both types of indicators. The values of *a* and *b* depend on individual preferences or can sometimes be derived from the Government's regulations (for example, the National Technical Regulation on Construction Planning promulgated by Circular No. 22/2019/TT-BXD of Vietnam Ministry of Construction, 2019).
– Group of categorical indicators (*Particles*, *Noise*, *GreenView*, *Drainage*, *RankingStreet*, *Area*, *Shape*, *Frontage*, *Depth*, *Location*, and *BusinessZone*): For each indicator, the most favourable value for the land price is chosen as the base value with a scale of 1.0. The scale of a given value is the ratio between the average land prices for the given and base values (note that the parcel samples used for comparison should have similar characteristics in other indicators). For example, in terms of *Location*, the 1st location group is chosen as the base because it has the highest land value. Then the *i*th location group is scaled as follows:

$$S_{location\_i} = \frac{\overline{P}_i}{\overline{P}_1},\ i = 2,3,4, \quad (1)$$

where $\overline{P}_1, \overline{P}_i$ are the average land prices of the 1st and *i*th location groups.

To cope with geographical inhomogeneity of some categorical indicators, we divided the study area into three zones, which are differentiated by developmental conditions based on the State's ranking of streets (high, medium, low) and field survey. Zone 1 is the high-ranking streets with the greatest profitability. Zone 2 is the medium-ranking streets with less profitability than zone 1. The rest belong to zone 3.

– Group of remaining indicators: *GreenDensity*, *Choice_global*, *Choice_local*, *Connectivity*, *Integration_global*, *Integration_local*. These are indicators without specific classification and/or thresholds in regulations. In fact, the higher these values are, the better the ratings are. In this study, we proposed a scale of 1.0 that corresponds to values greater than or equal to the mean value of each indicator. The graph of the membership function of these indicators is similar to Figure 3b (with *a* is the mean value, *b* = 0, and *x* is the indicator value).

The final step is to calculate each dimension index I_{dim_h} (h = 1...6, see Table 1) as the weighted sum of scales of its n_h indicators and then the composite UQoL index (I_{UQoL}) as follows:

$$I_{dim\_h} = \sum_{i=1}^{n_h} W_{hi} S_{hi}, \quad I_{UQoL} = \sum_{h=1}^{6} I_{dim\_h}, \quad (2)$$

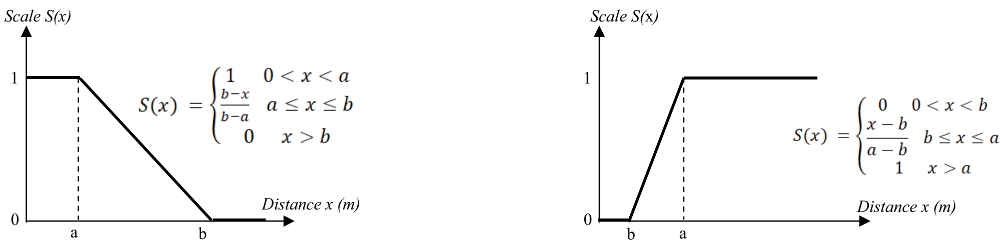
where W_{hi} and S_{hi} are the weight and the scale of indicator *i* that belongs to dimension *h*. The value of the UQoL index ranges from 0.0 to 1.0. The value of 1.0 indicates that the living conditions fully meet prescribed standards or are in accordance with the preferences of the majority. The lower values represent the degree to which these standards and preferences are satisfied in a specific urban area.

2. Results of calculation of UQoL index in Cau Giay District

2.1. Spatial distribution of residential land price

Using the dataset of 427 collected samples, the kriging interpolation was performed to reveal the spatial distribution of residential land prices in Cau Giay District. The obtained results (Figure 4) show that the residential land prices in the district vary in a wide range from 34.5 to 550 million VND/m^2 (or 1,500–23,700 USD/m^2 since 1 million VND is roughly equivalent to 43 USD). The lowest price is observed in Yen Hoa Ward, while the highest prices are observed in three areas that can be considered as the status poles in the district: 1) the Thang Long International Village, 2) the Dich Vong New Urban Block, and 3) the Trung Hoa – Nhan Chinh New Urban Block.

The Thang Long International Village is one of the first new urban projects in Hanoi City (started in 1996 and completed in 2003). It has a favourite location in the district's centre, near Nghia Do Park and the Museum of Ethnology, which are the "highlights" of the entire area. A quick survey of local citizens confirms this, where 12/18 (66.7%) respondents agreed that this is a highly attractive area in Cau Giay District.



a) b)

Figure 3. Membership functions for scaling distance indicators: a – positive case; b – negative case

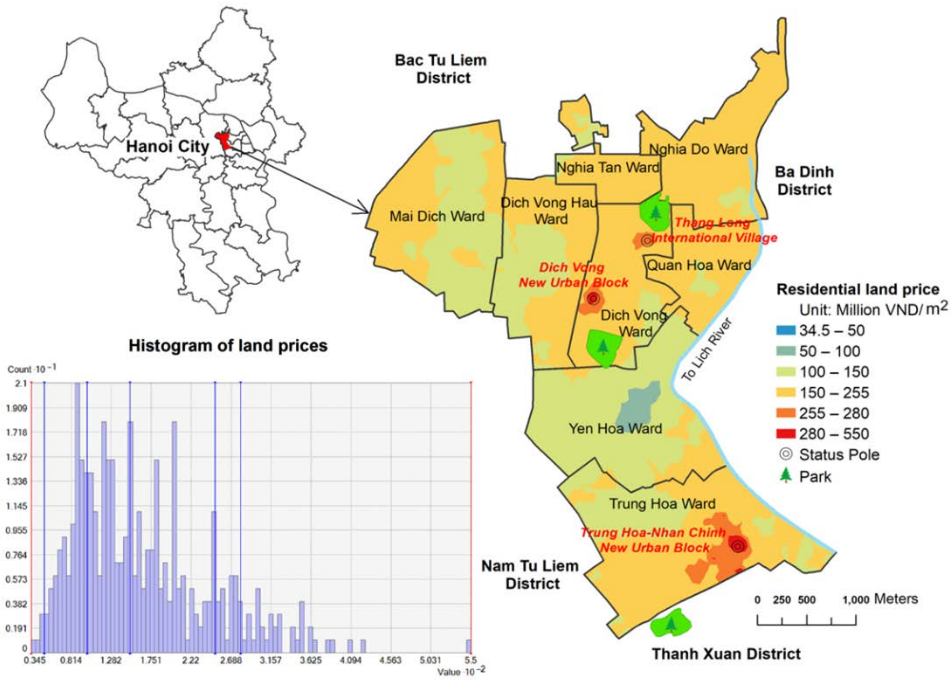


Figure 4. Spatial distribution of residential land price in Cau Giay District

The Dich Vong New Urban Block is a relatively young project (started in 2007 and completed in 2016). It is located near Cau Giay Park with modern and complete infrastructure that includes a full range of high-standard public services for people. A quick survey shows that 14/15 (93.3%) respondents considered this area highly attractive.

The Trung Hoa – Nhan Chinh New Urban Block (constructed from 2001 to 2006) is one of the most famous new urban blocks in Hanoi, which has the reputation of a new urban lifestyle trend. The area around this new urban block is highly integrated and is considered as one of the new centres of Hanoi City (Le et al., 2019). Some previous surveys also showed that the Trung Hoa – Nhan Chinh New Urban Block can be qualified as a status pole of Hanoi City (Bui et al., 2017). According to our quick survey data, 10/15 (66.7%) respondents considered this area highly attractive.

2.2. Correlation analysis and weighing indicators

The analysis of correlation between the residential land price and the UQoL indicators was carried out by using SPSS® software. The results are shown in Table 2. As noted earlier, the significant value (Sig.) must be less than 0.05. Therefore, 11 indicators were filtered out and 23 indicators (highlighted in *italics* in Table 2) were selected for further analysis. Some indicators seem important for land valuation, such as *Market* and *University*, but they were unselected for Cau Giay District. This can be explained by the fact that Cau Giay District has a relatively large number of universities and supermarkets, so the differentiation is low for these indicators across the district. Therefore, they become less important than other indicators. Since 23/34 indicators passed the correlation analysis, there is a notable interrelationship between the UQoL and the land price. This interrelationship is easier to be recognized and quantified if the land price is analysed using the SQTO approach. The reason is that many UQoL indicators are based on human preferences (see the weighing and scaling sections below), while according to the SQTO theory, the status component of the land price is based on the human preferences too.

To weigh the indicators using the ANP method, the connections between them were determined through the correlation analysis. The relationship between the indicators is expressed by an ANP network diagram, as shown in Figure 5. The network consists of 6 clusters corresponding to the 6 dimensions of UQoL, and 23 nodes that are those 23 indicators selected by the correlation analysis (Table 2). All clusters have inner dependence (or loop), except the social cluster, because the three nodes in this cluster are not correlated with each other. The two-way arrow lines indicate the outer dependence of clusters (Saaty, 2004).

In the ANP judgement step, three experts were asked for their opinions that served as input for the Super-Decision® software. These experts included a local land manager, a private land broker, and a property market researcher – all had at least five years of experience. The experts were asked to fill out reciprocal matrices in a questionnaire to compare the importance levels of each pair of UQoL indicators that affect another indicator. If the experts' opinions seemed inconsistent, the adjustment of judgement was inferred from the degree of correlation among the indicators in the correlation analysis. This contributed to increasing objectivity in the assessment.

Table 2. Correlation between residential land price and UQoL indicators

ID	Indicators	Pearson correlation	Significant (*2-tailed*)	ID	Indicators	Pearson correlation	Significant (*2-tailed*)
1	Particles	0.044	0.369	18	*Park*	*–0.117**	*0.018*
2	Noise	0.042	0.387	19	Market	–0.011	0.819
3	*GreenDensity*	*0.240***	*0.000*	20	*School*	*–0.112**	*0.022*
4	*GreenView*	*0.137***	*0.005*	21	UrbanBlock	–0.035	0.480
5	*Pollution*	*–0.134***	*0.006*	22	MainStreet	–0.045	0.356
6	*Drainage*	*–0.162***	*0.001*	23	*ComHouse*	*–0.164***	*0.001*
7	*RankingStreet*	*–0.139***	*0.004*	24	Administrative	–0.082	0.096
8	*Area*	*0.275***	*0.000*	25	*Police*	*–0.114**	*0.020*
9	*Shape*	*–0.117**	*0.017*	26	*Recreation*	*–0.106**	*0.031*
10	Frontage	0.034	0.482	27	*Religion*	*–0.216***	*0.000*
11	Depth	0.000	0.993	28	*HistoricalSite*	*–0.098**	*0.045*
12	*Integration_global*	*0.240***	*0.000*	29	*Cemetery*	*–0.191***	*0.000*
13	*Integration_local*	*0.297***	*0.000*	30	*Hospital*	*–0.143***	*0.003*
14	*Choice_global*	*0.263***	*0.000*	31	*TransStation*	*–0.160***	*0.001*
15	Choice_local	0.077	0.111	32	University	–0.006	0.905
16	*Connectivity*	*0.112**	*0.021*	33	*Location*	*–0.419***	*0.000*
17	*BusStop*	*–0.139***	*0.005*	34	BusinessZone	0.075	0.122

Note: * The correlation is significant at the 0.05 level (2-tailed); ** The correlation is significant at the 0.01 level (2-tailed). Selected indicators are highlighted in italics.

Table 3. Calculated weights of selected indicators (nodes)

ID	Nodes/Indicators	Weights		ID	Nodes/Indicators	Weights	
		Calculated	Normalised by cluster			Calculated	Normalised by cluster
3	GreenDensity	0.039	0.274	18	Park	0.044	0.162
4	GreenView	0.023	0.161	20	School	0.036	0.134
5	Pollution	0.049	0.348	23	ComHouse	0.050	0.382
6	Drainage	0.031	0.217	25	Police	0.037	0.281
7	RankingStreet	0.067	0.489	26	Recreation	0.044	0.337
8	Area	0.047	0.342	27	Religion	0.041	0.262
9	Shape	0.023	0.169	28	HistoricalSite	0.059	0.372
12	Integration_global	0.046	0.171	29	Cemetery	0.058	0.366
13	Integration_local	0.072	0.266	30	Hospital	0.047	0.290
14	Choice_global	0.021	0.078	31	TransStation	0.059	0.365
16	Connectivity	0.013	0.048	33	Location	0.056	0.345
17	BusStop	0.038	0.141				

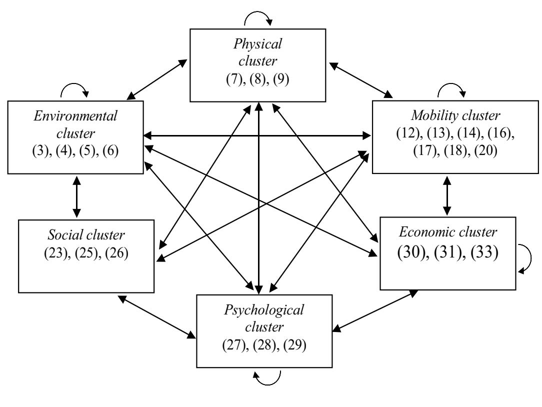


Figure 5. Network structure in ANP

Table 3 shows the calculated weights of the nodes (indicators). One can see that higher weight values are observed mostly in the mobility, physical, and economic dimensions, such as *Integration_local*, *RankingStreet*, and *Location*. Some lower weight values are *Connectivity* and *Choice_global*. It should be noted that these weight values are specific to Cau Giay District and may not be applicable to other areas with different characteristics.

2.3. Scaling indicators

The selected indicators were classified into three groups for the scaling purpose:
- Group of numerical (distance) indicators: The pedestrian-friendly principle is a priority in construction

Table 4. Scaling of categorical indicators

Indicator	Category	Zone 1	Zone 2	Zone 3
RankingStreet	High	1		
	Medium		1	
	Low			0.88
Location	1st	1	1	1
	2nd	0.91	0.87	0.89
	3rd	0.86	0.75	0.60
	4th	0.71	0.59	0.47
Area	<50 m^2	0.93	0.95	0.98
	50–90 m^2	1	1	1
	>90 m^2	0.89	0.85	0.91
Shape	Square, rectangle	1		
	Trapezium	0.98		
	Others	0.83		
GreenView	0 (No)	0.93		
	1 (Yes)	1		
Drainage	0 (Poor)	0.96		
	1 (Good)	1		

planning in Vietnam, as well as for the UQoL. According to Circular No. 22/2019/TT-BXD of the Vietnam Ministry of Construction, the service radius of urban facilities is 500 m. Based on that, the membership function in Figure 3a has *a* parameter of 500 m. The maximum threshold parameter *b* is proposed to be 5000 m based on the farthest distance of the research area's extent. In Figure 3b, *a* equals 500 m and *b* equals 0 m.

– Group of categorical indicators: Table 4 shows the scales of these categorical indicators. In terms of the *RankingStreet* indicator, the high level and medium level have a scale of 1.0 because the field survey data show that land parcels in these areas have almost the same price.
– Group of remaining indicators: the membership function in Figure 3b has *b* value of 0, and *a* value equals the mean value of each indicator (*a* = 7% for *GreenDensity*, 1010 for *Integration_global*, 140 for *Integration_local*, 16 for *Choice_global*, and 4 for *Connectivity*).

2.4. Final calculation and visualisation of UQoL index

The indicators' scales and weights were combined using Equation (2) to produce the six dimension indices as shown in Figure 6 (right side). The obtained dimension

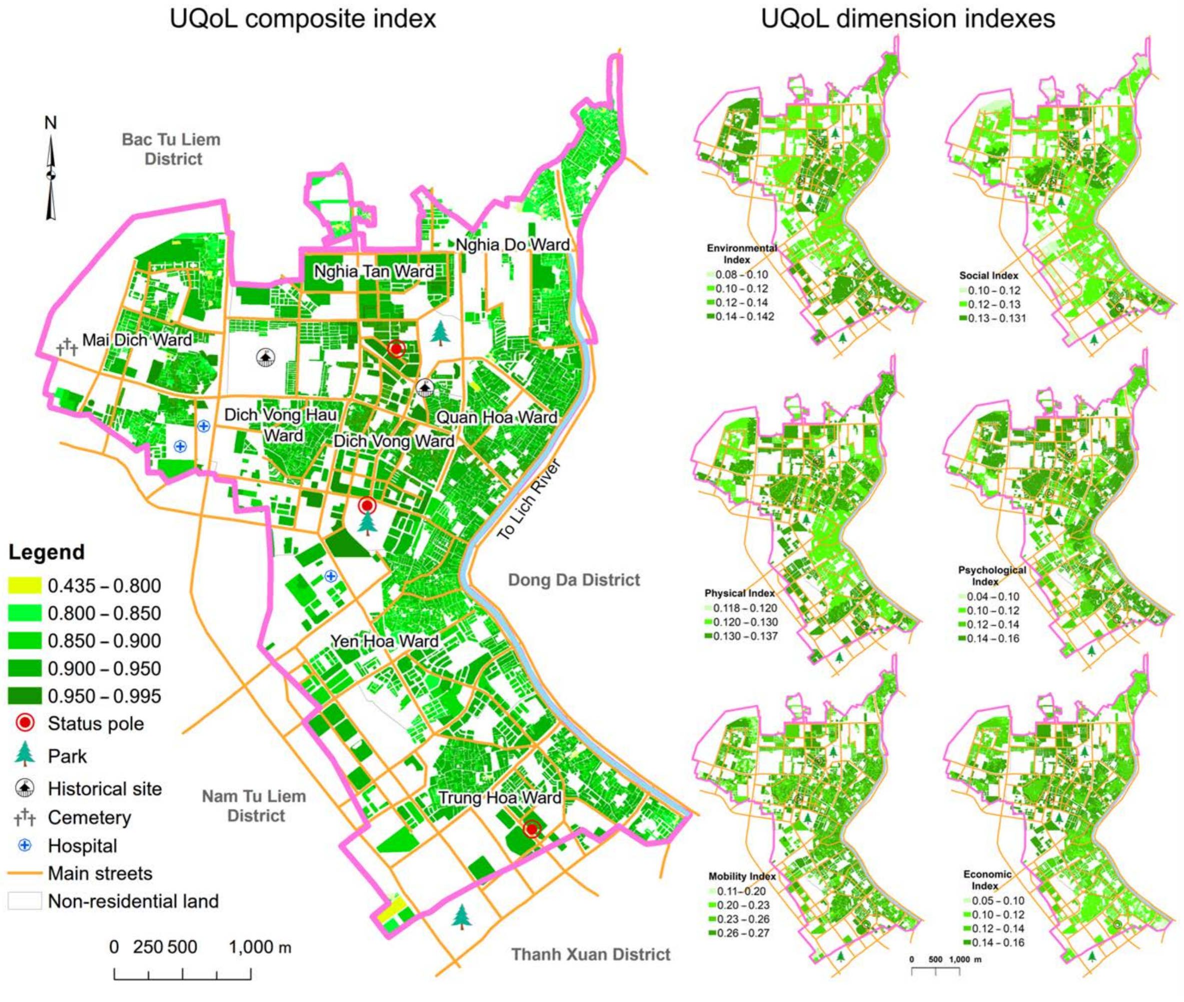


Figure 6. Maps of UQoL index and dimension indices in Cau Giay District

indices were then aggregated into the composite UQoL index (hereafter called the UQoL index). The results were then visualised as a thematic map using ArcGIS® software (Figure 6, left side). In this map, the yellow colour represents areas with the lowest values of the UQoL index (0.435–0.800), while the dark green colour represents areas with the highest values (0.950–0.995). The white colour denotes areas with non-residential land use types, such as public land, land for offices, schools, enterprises, etc. These land use types are out of scope of this research. For comparison purposes, the previously identified status poles are also displayed on the map as red circles.

3. Discussion

3.1. Distribution of UQoL index in Cau Giay District

Analysing the map in Figure 6, we can see that the areas around the three status poles have mostly high values of dimensional indices, such as environmental, physical, mobility, and social ones. In general, the characteristics related to the street network, and the spatial accessibility from parcels to urban facilities are relatively equal throughout the district. Meanwhile, for the environmental index, the lowest value is observed near the To Lich River, which is strongly contaminated by waste water. Areas with the highest environmental index are observed near parks, such as Nghia Do, Cau Giay, and Thanh Xuan parks. As for the psychological index, it has low values near cemeteries, and high values near historical sites, such as the Thanh Chua Pagoda and the Ha Pagoda. In terms of the economic index, the north of Cau Giay District has a higher rank than the south because many hospitals, universities, as well as convenient streets for business are located in the north. These are favourable conditions for running retail businesses which are very popular in Hanoi City.

It can be seen that the values of the UQoL index differ significantly from ward to ward. Among the eight wards, Dich Vong Ward has the highest (i.e. the best) UQoL index with two most prominent sites: 1) the Dich Vong New Urban Block located near Cau Giay Park, and 2) the Thang Long International Village located near Nghia Do Park. It is clearly seen that the status poles identified in Figure 4 are well matched to the areas with the highest UQoL index, although the Trung Hoa – Nhan Chinh New Urban Block has a bit lower UQoL index (second rank) than it was expected from the high land price in this area. In addition, in Mai Dich Ward, there is an area with a high UQoL index, but the land price only ranks third. The reason may be due to the large cemetery and the funeral home located in this ward. In general, each ward of the district has attractive and unattractive sites. However, the less attractive sites are more clustered in Yen Hoa, Trung Hoa, Nghia Tan, and Nghia Do wards. The low index values are primarily due to the relatively poor condition of the environmental, social, and economic dimensions. In fact, the land prices at these sites are also ranked medium and low in the district.

3.2. Interrelationship scenarios between land price and UQoL index

According to the SQTO theory, the land value consists of two components: status and quality (or nonphysical and physical attributes). The quality component is more stable, while the status component is more dynamic, representing wealth, culture, environmental quality, etc. (Hoang & Wakely, 2000). Meanwhile, to adequately investigate the aspects of UQoL, subjective indicators related to individual perspectives (i.e., dependent on age, culture, socio-economic status, education, etc. of each person) and objective indicators should be employed. Therefore, in terms of structure, there is a similarity in the components of land price and UQoL. In fact, there are four possible scenarios for the interrelationship between UQoL index and land price as follows (Figure 7):

- 1st and 2nd positive directions: high land price – high UQoL index, and low land price – low UQoL index. These scenarios are features of socio-economic and political environment under normal conditions, with no major changes. In Cau Giay District, the two status poles in Dich Vong Ward with a high UQoL index, and the area in Yen Hoa Ward with a low land price and a low UQoL index are examples of these scenarios.
- 1st negative direction: high land price – low UQoL index. This means the high land price does not conform to the quality of the surrounding facilities. The cause may be in an undiscovered status, a speculation, or a good circulating rumour. The "real estate bubble", as suggested by SQTO, is a prime example (Hoang, 2015). Another possible explanation is that the perception of UQoL for the generally higher income group of residents might tend to be more demanding, that is, the case of an inverse relationship between income and satisfaction. In Cau Giay District, the case of the Trung Hoa – Nhan Chinh New Urban Block, although it is not a typical example for this scenario, shows a small asynchronism between the land price and the UQoL index.
- 2nd negative direction: low land price – high UQoL index. This situation is unlikely to occur frequently, but does exist in reality. In Cau Giay District, the case in Mai Dich Ward represents this scenario due to the negative status indicator of the cemetery and funeral house. Another explanation of this scenario is the inverse relationship between income and satisfaction described above for the 1st negative scenario. The areas with 2nd negative scenario bring opportunities for doing real estate business since the status poles do not appear randomly, but must be based on certain favourable conditions. Areas with a high UQoL index have high potential for investment, contributing to the formation of status poles.

As suggested by the SQTO, the match between housing status and dwelling quality is a dynamic process, so the stable positive interrelationship between them is expected

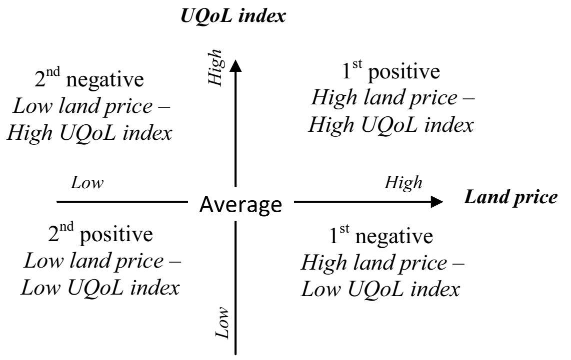


Figure 7. Four scenarios of interrelationship between land price and UQoL index

to be more likely in mature settlements. In contrast, negative interrelationships can be observed in newly established urban areas or in areas where the status and quality components have not yet caught up with each other. The hidden issues should be analysed with more care and are the subjects of further research.

3.3. Application of UQoL index and further research

The UQoL index presented in this article is market-centric, as it was based on the norms and preferences of the real estate market. The UQoL index map is a projection of the real estate market, and by coupling with a land value map, it can hint at the state of the real estate market: where it is matured (positive scenarios) or where it is less developed (negative scenarios). This feature helps stakeholders, especially the land managers, to analyse the market, forecast changes of land price, and develop intervention measures to stabilise the market. For example, the UQoL index map can be used in property appraisal to compare the characteristics of land parcels or houses. It can also be used in forecasting the formation or shift of status poles, e.g., where the UQoL index has not yet reached a high value, new status poles will have more chance to appear under socio-economic development activities. As noted in the previous subsection, the application of UQoL for leveraging the change of status poles as a way to manage the real estate market is an interesting subject of further research.

This study analysed UQoL at the land parcel level, which is considered as the most detailed level from the housing perspective. Therefore, it can be expected that the obtained results are reasonably reliable. However, the limitation of the study is that it did not take into account several indicators related to population characteristics, such as income, education level, occupation, etc., as well as statistical data over a long period of time. We found it necessary to combine a census survey with a land price survey. Thus, the information will be updated regularly and there are more indicators available for the analysis of UQoL, as well as for land valuation. In fact, the determination of UQoL related factors (or indicators) and their impact is an important part of the property valuation process. Another advantage of calculating indices is that, since UQoL is quantified, it can be easily compared and monitored over different periods of time.

Conclusions

This article proposed a market-centric UQoL index that uses land price as an input and is based on the SQTO theory and ecosystem services. The UQoL index reflects, at a certain level, the state of the real estate market and helps to identify where the market is matured or where it is less developed. The UQoL index can be used as a reference in analysing, forecasting changes, and developing market intervention measures.

There are four possible scenarios for the interrelationship between UQoL and land price: two positive scenarios where the land price matches the UQoL, and two negative scenarios where they are unmatched. The negative scenarios can be observed in newly established urban areas or in areas where the status and quality components of the land have not yet caught up with each other. These scenarios are of high interest to the market stakeholders as they can bring many business opportunities.

The limited volume of the available dataset did not allow this study to take into account several indicators related to population characteristics, such as income, education level, occupation, etc.; and to investigate the interrelationship between UQoL and land price across a large time span. Therefore, the aim of the ongoing research is to improve the method of calculating the UQoL index with larger datasets and the application of machine learning to explain the mechanism of formation of negative scenarios using the SQTO theory, and to use the UQoL concept in manipulating status poles to manage the real estate market.

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Disclosure statement

The authors declare that there is no conflict of interests.

Dataset

The dataset of this article is available at FigShare with DOI: https://doi.org/10.6084/m9.figshare.21441243

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