Application of Space Syntax and GIS in Assessment of Accessibility Factors Affecting Urban Residential Land Values
(a Case Study in Trung Hoa – Nhan Chinh Area, Hanoi City)

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Key words: Space syntax, accessibility factors, urban land value, Trung Hoa-Nhan Chinh area

SUMMARY

Transport network is an underlying force in location, growth, rank-size and functional differentiation of cities. Apart from economic role, transport network plays an important role in formation of urban societies, because it exhibits a very close relation to the style of life, and meets requirement of connection with society of people, such as working, shopping, studying, etc. The more easy access from land parcels to recreation sites (e.g. parks), schools, or urban centers, the higher land values are, and vice versa.

The objective of this study is to assess those accessibility factors that have the most impact on urban residential land values in Trung Hoa – Nhan Chinh area. Trung Hoa – Nhan Chinh area is located in the South-western of Hanoi City, and it is considered as one of "new centers" of Hanoi. The accessibility factors are analyzed by space syntax, network analysis, as well as correlation analysis methods. The space syntax method is used to calculate street configuration measures (connectivity, integration). The network analysis method is used to calculate distances from each parcel to the nearby urban blocks, hospitals, markets and parks. GIS is a foundation to integrate the results of space syntax analysis and network analysis in a geodatabase. Finally, correlation analysis is carried out to reveal those factors that have most impact on urban residential land values. In the study area, we identified five main accessibility factors: 1) street ranking, 2) location of land parcel, 3) integration, 4) distance to the urban blocks, and 5) connectivity.

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1. INTRODUCTION

Urban residential land values are formed by various factors, which are determined by land characteristics, distinctive environmental qualities, as well as interrelation of all other urban components. In an urban structure, transport network is one of the most important components, defining the accessibility of urban objects, including land parcels. In network theory, the accessibility is defined as "the extent of overcoming friction that acts spatially and the characteristics of the related space itself" (Min, Moon, & Kim, 2007). Here, the friction can be travel time, travel cost, or travel distance to pass between two nodes (Min et al., 2007). In space syntax theory, accessibility could be analyzed by spatial configuration according to the street network. Configuration is defined not simply as connections, but as "relations that take into account other relations" (Hillier, 2007). It refers to the way in which spaces are related each to others, not only pair-wise but also the overall pattern that they constitute. These are topological relations.

The Space Syntax and GIS have been successfully applied to many urban studies, including urban residential land value studies. Kahraman and Kubat (2015) confirmed that Space Syntax plays a significant role in estimating tax values in central business districts in the accessibility context with reference to Izmir, a coastal city of Turkey (Kahraman & Kubat, 2015). Lee and Kim (2009) found that space configurational characteristic factors have greater influence on the formation of land price than that of land use characteristic variables in Seochodong area in Seoul, Korea (Lee & Kim, 2009). Topcu (2009) analyzed accessibility effect on urban land values in Istanbul, Turkey using the following parameters: 1) metric distance between every single street and public service units stand at the nearest location of the streets (16 parameters), and 2) spatial integration value in urban and neighborhood scales. Stepwise regression analysis revealed five most relevant parameters: 1) distance of the street from the sea, 2) distance to central business districts (CBDs), 3) integration values, 4) distance from the universities, and 5) distance from sanitary facilities (Topcu, 2009). Morales et al. (2017) developed a multivariate regression model that used the following access metrics in Guatemala City: 1) geographic access indexes that were computed using time-based analyses per transport mode (including public transport and private vehicle); 2) geometric access metrics estimated via Space Syntax at various spatial scales; 3) a proposed geometric via geographic access metric computed as a potential access to network centrality as analysed in Space Syntax. The study showed that geometric accessibility brings spatialized and localized information that contributes to a parsimonious model and better explains the variability of land-values (Morales, Flacke, & Zevenbergen, 2017). Up until now, research on accessibility considered the distance, time and spatial configuration of street network. However, in reality, the urban transport network is a collection of different levels of streets based on many criteria. The above reviewed researches focused on the spatial configuration, but did not show the difference in the hierarchical attributes of streets. Moreover, the access factors should be considered in terms of the accessibility of vehicles to land parcels depending on the width of the road. For example, there are narrow alleys of less than 2m width, so cars cannot enter. Hence, that is also one of the limitation factors negatively affecting on land prices.

In Vietnam, for the purpose of valuation, urban land parcels in each province or city are classified into four location groups based on their relative position with streets. In Hanoi City, the first group consists of land parcels that are adjacent to named street; the second, third and fourth groups consists of land parcels adjacent to the streets or branches of streets with the width of more than 3.5m, 2.0-3.5m, and less than 2.0m accordingly (People's Committee of Hanoi, 2014).

With a desire to improve the accuracy of urban land valuation, this study aims to evaluate the accessibility factors affecting urban residential land values. Accessibility factors are defined by the metric distance measures from each land parcel to facility locations, the topological distance measures through spatial configuration analysis, as well as the location of land parcel relative to adjacent street(s). However, the streets were not considered as the same, they were classified by level.

2. THEORETICAL BACKGROUND

2.1. Status – Quality Trade Off theory (SQTO)

Urban land value is fundamentally determined by its locational attributes. "Where is the land located?" is one of the seven questions should be carefully analyzed for an accurate measurement of urban land value (Özdilek, 2011). However, to answer this question depends on various approaches. In this study, the concept of accessibility is used to assess the location. Segal (1979) identified that "Accessibility of the neighborhood in terms of the sites to which the household commonly travels" is one of the five major characteristics used when evaluating the attractiveness of a residential location (Jordaan, Drost, & Makgata, 2004).

Most studies analyzed accessibility based on the theory developed by Alonso (1964) and Muth (1969), which indicates that urban land value depends on distance from the city centers (Morales et al., 2017). However, with the development of urban infrastructure and policies of management bodies, the number of centers or poles of the city tend to increase to become the multi-polar cities and the physical distance has become less important. Moreover, the demand for living space is increasingly diverse. Status – Quality Trade Off theory (SQTO), which was developed by Hoang Huu Phe and Patrick Wakely, proved that Alonso's model was a case of SQTO (Phe & Wakely, 2000). According to SQTO, residential areas in cities make up largely continuous and overlapping rings around the status pole or poles. The ring pattern is the outcome of a trade-off between that desirable status and an acceptable level of dwelling quality (Phe & Wakely, 2000). Status poles represent the highest points of social desire (such as environmental quality, education, culture, etc.). Especially, in the quality – status model, the physical distance can be calibrated to become the status distance. Because each status pole has a different range of influence. And so, the accessibility based on SQTO implies the distance from the land parcel to status poles. Figure 1 illustrates the multi-polar city and the status distance.

SQTO is the dynamic description of the formation and development of urban residential areas in various socio-economic forms. In general, it is increasingly well-known in the field of urban studies (Hoffman, Belsky, & Lee, 2006) and applying in many researches related to choice of urban living space (Jun, 2006; Kim, 2010) as well as housing price estimation (Comber et al., 2016; Thanh, Hiep, & Phe, 2017).

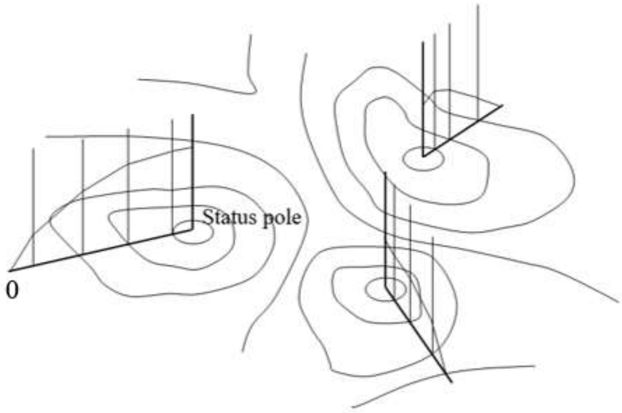

Figure 1. Model of multi-polar city (Phe & Wakely, 2000)

2.2. Space Syntax

Space Syntax, developed by Hillier and Hanson in the 1970s, is a theory, as well as a method for analyzing patterns of architectural space, at both the building and the urban level. It attempts to explain human behaviors and social activities from a spatial configuration point of view (Hillier, 2007). Configuration describes the position of each space in relation to all the others. Likewise, Space Syntax measures the configuration based on topological relationships rather than on metric distances.

The unit of Space Syntax technique can be described in three geometric types: 1) linearly (or axial lines) to study movement, 2) convex space (in which every point can see each other), and 3) isovist (often spiky visual field). In urban level, an important spatial data is the street network, which are axial lines in the terminology of Space Syntax.

The most commonly used Space Syntax measure is integration. A global integration analysis implies calculating how spatially integrated a street axis in term of the total number of directional changes to all others streets in a city (Nes, 2014). A space is said to be integrated when all the other spaces of the streets are relatively shallow from it. It is clear that the center has the highest integration, and that integration reduces evenly in concentric rings around the center. This concerns the degree of accessibility, in terms of the fewest changes of direction. Figure 2 illustrates the integrated space and segregated space. The left part of this figure is the most segregated space (calculated for space 1) because from the space 1, in order to access space 4, we have to pass 3 steps. In contrast, in the right part of Figure 2, there is only 1 step from space 1 to space 4. Therefore, the right part is the most integrated space (calculated for space 1).

Connectivity is another important Space Syntax measure. This refers to the number of other axial lines or spaces that are directly connected to any one line or space.

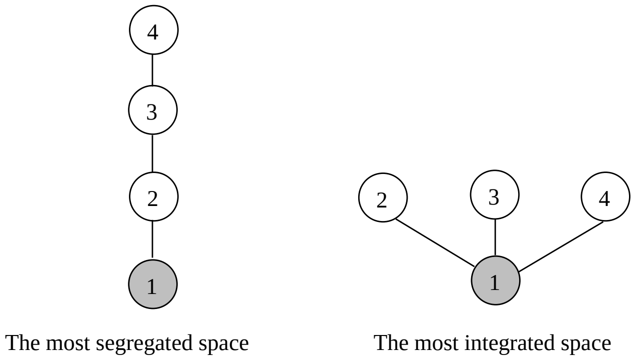

Figure 2. Illustration of segregated space and integrated space

Based on the ability of definition of urban space, as well as techniques for analyzing cities as networks of space formed by the placing, grouping and orientation of buildings, Space Syntax makes it possible to develop a set of theories about how urban space networks relate in general to the social, economic and cognitive factors which shape them, and how they are affected by them (Hillier, Turner, Yang, & Park, 2007).

3. METHODOLOGY

This study was conducted in 3 stages (Figure 3).

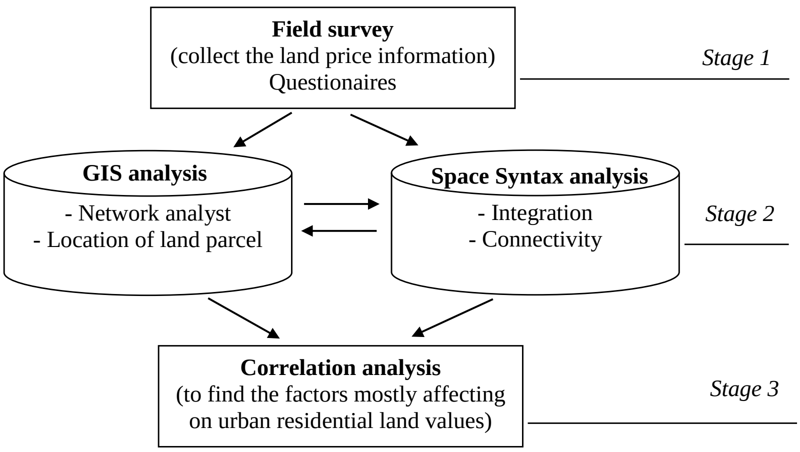

Figure 3. Research stages

Stage 1: Field survey

The purpose of field survey is to collect information about land parcels traded on the market. The most important information is land price. This survey was conducted by using questionnaires during fieldwork (December 2017-January 2018). There were 32 questions grouped by 4 sections including: landowner information (occupation, number of family members, phone number,…); land parcel information (address, area, shape, location, year of transaction, land price, land tenure certificate,…); house information (house type, number of floors, year of construction, house price,…); and supplement information (electricity and water supply service, security situation, the nearest favorite areas,…). The sampling method is based on streets in all four location groups of each street. The sampling is limited to transactions within timeframe of recent 3 years (from 2015 to 2017 year) under normal trading conditions (e.g. excluding transaction within a family, or under forced conditions,…). Sources of price information mainly come from land owners. Moreover, we also refer to the basic prices from the third parties (e.g. real estate agents) in order to detect abnormal land prices. The sample locations are indicated on a cadastral map to check for correctness and to manage a good distribution over the study area.

After surveying, the data set was analyzed to make adjustment and filter out samples with inappropriate land prices, such as outdated (normally more than 3 years old) transactions, or abnormal prices. Sometimes, house prices should be separated from land prices by traditional land valuation methods, such as income analysis, cost analysis. The land prices are normalized in local currency of million VND per square meter and stored in a GIS database.

Stage 2: GIS and Space Syntax analysis

The purpose of GIS analysis is to classify the location of each parcel relative to the adjacent street into one of four location group as described in session 1, and calculate the distance from each parcels to the nearest amenities, e.g. hospital, parks. Based on GIS database, using Select by Location and Select by Attribute tools according to the width of streets in ArcGIS software, location group of each parcel can be identified. In this step, land parcels and streets are stored as polygon feature classes. However, to run Network Analyst tools to define distance value, the street feature class must be converted to lines, meanwhile, land parcels and amenities are converted to points. This street network is also used in Space Syntax analysis in DEPTHMAP software and it is called axial map. This street network not only covers the case study area but also expanded to cover neighborhood areas. In this study, the expanded street network is a whole street network in urban districts of Hanoi City.

The purpose of Space Syntax analysis is to calculate the integration value and connectivity value. Connectivity is the number of lines directly linked to each individual line. For instance, line 1 in Figure 4 has connectivity of 2, and line 2 has connectivity of 3.

The axial map is transferred to segment map in DEPTHMAP software and spatial integration values are calculated by segment map at global level. The street segment is the section of axial line or street between two intersections. The integration value of a street segment is based on the mean depth or topological distance to all other segments in the network. Depth is measured in steps. The sum of the depths of a line to all the other lines of the axial map is called the total depth of that line (Teklenburg, Timmermans, & Wagenberg, 1993). The total depth values tend to get very large and are not easy to work with. Therefore, Space Syntax works with the mean depth of lines, which is defined as (Teklenburg et al., 1993):

$$\overline{D} = \frac{{}_{T}D}{L-1} \qquad (1)$$

$\overline{D}$: Mean depth
${}_{T}D$: Total depth
L: Numbers of lines in network

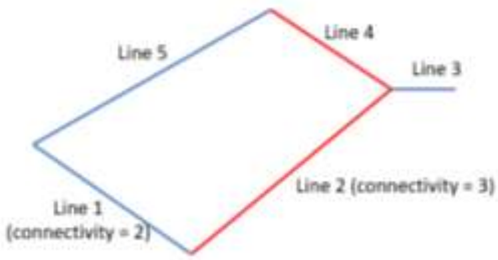

Figure 4. Illustration of connectivity value

The values of ${}_{T}D$ and $\overline{D}$ depend on the number of lines of an axial map. In order to be able to compare axial maps of different size, standardization value of integration measures is introduced. It is the relative asymmetry (RA) value and the real relative asymmetry (RRA) value (Teklenburg et al., 1993). Then the integration value is the inverse of RRA value (1/RRA).

$$RA = \frac{2 \times (\overline{D} - 1)}{L - 2} \qquad (2)$$

$$RRA = \frac{RA}{D_L} \qquad (3)$$

D_L: diamond value

$$D_L = 2 \times \left\{L \times \left[log_2\left(\frac{L+2}{3}\right) - 1\right] + 1\right\} / (L-1) \times (L-2) \qquad (4)$$

The result is then exported to the GIS database and attached (joined by location) to each land parcel sample.

Figure 5 provides an example of how to calculate the global integration of one street (number 4) to all other streets. The street number 4 is represented at the bottom of the graph, thus at step zero (or level 0). The streets number 2, 3, and 5 have step of 1 (level 1). The streets number 1, 6, and 7 have step of 2 (level 2).

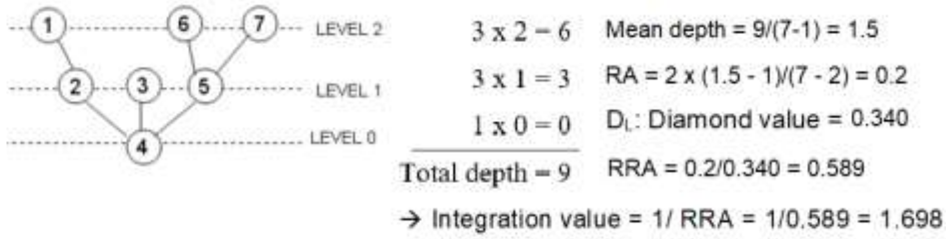

Figure 5. Example of how to calculate the global integration value

Stage 3: Correlation analysis

Correlation analysis is a method of statistical evaluation to study the strength of a relationship between two, numerically measured variables *X* and *Y*. In this study, this is the final stage to define correlation value between land price and each factor affecting urban residential land price. The correlation value is in the range of -1 to 1. The higher absolute correlation value is, the more strongly correlated to the land price, and vice versa. Therefore, the factors mostly affecting urban residential land values could be found. The correlation trend can be either positive or negative. Positive correlation exists if one variable increases simultaneously with the other. In constrast, negative correlation exists if one variable decreases when the other increases.

In this study, Pearson correlation (*r*) was used to measure the degree of correlation. The following formula is used to calculate the Pearson correlation with expected value μ_X and μ_Y and standard deviations σ_X and σ_Y

$$r = \frac{cov(X,Y)}{\sigma_X\ \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X\ \sigma_Y} \qquad (5)$$

where *E* is the expected value operator, *cov* means covariance.

This stage was conducted by SPSS software.

4. CASE STUDY AREA AND INPUT DATA

4.1. Description of case study area

The case study was carried out in Trung Hoa – Nhan Chinh area, which consists of 2 wards: Trung Hoa ward and Nhan Chinh ward. This area is located in the south-west of Hanoi City, and considered as one of new centers of Hanoi (Figure 6). A variety of remarkable objects are listed in this area, such as Vietnam National Convention Center, Big C Thang Long (Hanoi’s largest retail hypermarket), new urban areas, and main City's arteries, such as Tran Duy Hung, Le Van Luong streets. There are 22 named streets in this area and they can be classified in 3 levels (high, medium and low level) according to the State regulations (People's Committee of Hanoi, 2014). Apart from the main streets, there is also a large network of alleys. According to statistics from GIS database of study area, the number of alleys with a width of less than 2m accounts for about 60%. Trung Hoa ward is a well planned area, so the transport network structure is quite regulated. Meanwhile, Nhan Chinh ward is an older area, so there are more alleys. The new urban lifestyle trend, which has been formed in Trung Hoa – Nhan Chinh, although not yet completely stabilized, is the living in high apartment buildings. The target customer group of the area is mostly yuppie (young urban professionals).

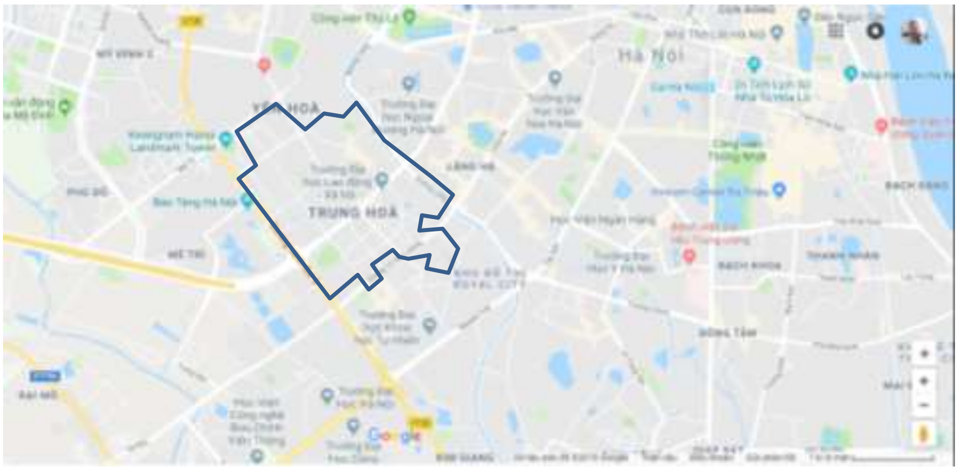

Figure 6. Location of the study area in Hanoi City

4.2. Input data

In order to determine the input data, it is important to identify the variables that need to be analyzed. In fact, those are the proposed factors affecting the urban residential land price in Trung Hoa – Nhan Chinh area. The criteria to propose those factors are 1) the characteristics of the study area and 2) the dimensions of urban quality of life. Firstly, Trung Hoa – Nhan Chinh area are well known with many urban blocks. Therefore, the distance from land parcel to urban blocks is one of the priority factors. Secondly, according to the urban quality of life dimensions in the study of Din et al. (2013), there are seven main dimensions: environmental; physical; mobility; social; psychological; economical; and political urban quality of life. The scope of this study only covers four dimensions: The first (environmental) dimension refers to the natural aspects of the neighborhood. The second (physical) dimension refers to facilities and services. The third (mobility) dimension focuses on the accessibility, transportation issues. The fourth dimension (economical) is related to the neighborhood as a place of economic activities (Din, Shalaby, Farouh, & Elariane, 2013). Hence, the proposed factors in this study are identified: distance to markets, distance to schools, distance to urban blocks, distance to parks and recreation objects, distance to hospitals, spatial configuration (including integration and connectivity). Moreover, factors related to ranking of street as well as location of land parcel are also proposed. In the correlation analysis, these factors are called independent variables and the land price is called the dependent variable. Table 1 describes the dependent variable and independent variables in this study.

Table 1. Dependent variable and Independent variables

Type of variable	Name of variable	Notes
Dependent variable	Urban residential land price	Market price
Independent variable	Integration	
	Connectivity	
	Distance to hospitals	Include hospitals and clinics
	Distance to schools	Include high schools, secondary schools, and primary schools
	Distance to markets	Include supermarkets and markets
	Distance to urban blocks	
	Distance to parks	Include parks and urban green spaces, recreation objects
	Ranking of street	Include high, medium, and low level
	Location of land parcel	Classified into one of location groups 1, 2, 3 and 4

Input data used in this study consists of spatial data and attributive data. Spatial data include street network of Hanoi City (Figure 7a), cadastral maps of Trung Hoa and Nhan Chinh wards, and 76 standardized survey samples as a point layer (Figure 7b). Other spatial data related to facilities can be extracted from the cadastral map, including points of hospitals, points of schools, points of markets, points of urban blocks, points of parks. The attribute data is the information of samples. The most important attribute is urban residential land market price.

Figure 7. Spatial data of the case study in Trung Hoa – Nhan Chinh Area

5. RESULTS AND DISCUSIONS

5.1. Network analysis

The Closest Facility tool in Network Analyst extension of ArcGIS software was used to calculate the shortest distance from each land parcel to the closest facilities. For using this tool, it is necessary to identify two components: 1) "Incident" refers to land parcel and 2) "Facility" refers to points of urban blocks, markets, or parks. Figure 8 illustrates the routes of shortest distance to urban blocks. Table 2 shows the statistics of distance value.

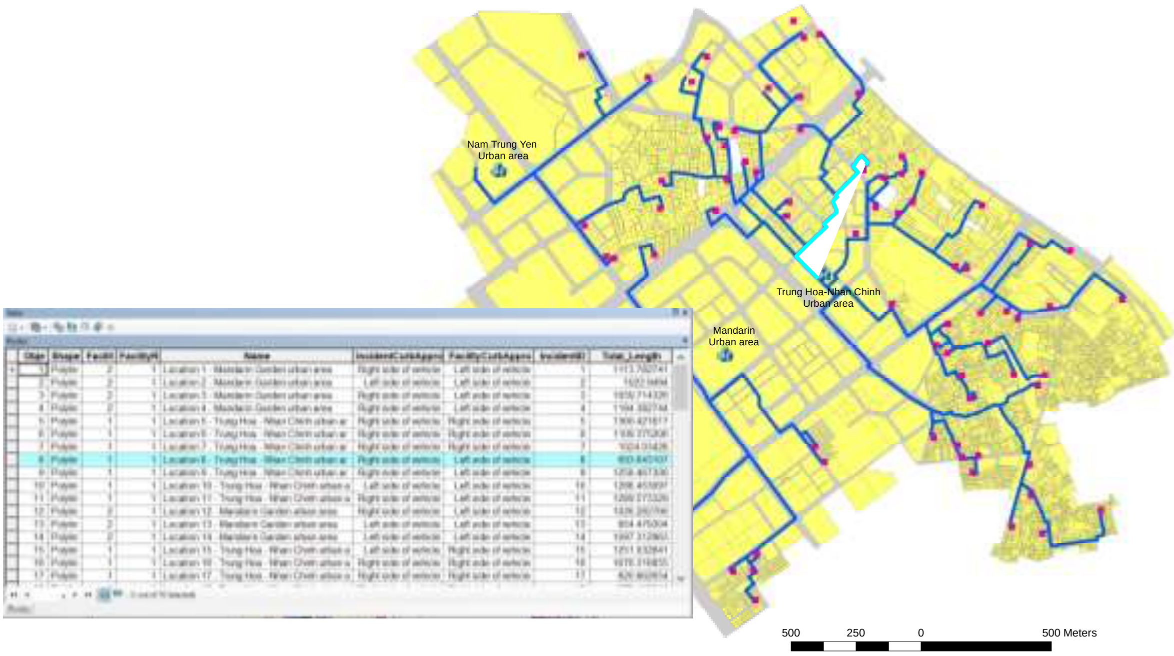

Figure 8. Analysis of the shortest distance to the closest urban block

Table 2. Statistics of distance value (n=76, unit: meter)

Measures	Minimum	Maximum	Mean	Standard Deviation
Distance to hospitals	46.89	1743.47	598.85	422.16
Distance to schools	14.8	736.60	354.93	162.99
Distance to markets	73.38	1348.83	664.08	316.74
Distance to urban blocks	305.25	2021.24	948.04	312.27
Distance to parks	10.5	509.2	184.89	125.11

According to Table 2, we can see distances to facilities with a mean of less than 1000m, the maximum distance is about 2000m. This indicates the easy accessibility from the land parcels to facilities. It also implies a well-balanced distribution of facilities in the study area. In fact, the rationality of urban planning in Trung Hoa – Nhan Chinh area is highly appreciated by specialists and community.

5.2. Integration analysis

In order to examines the the global integration of the street network in Trung Hoa – Nhan Chinh area, the integration analysis should be carried out in the scale of street network of Hanoi City. Figure 9 shows the result of integration analysis of Trung Hoa – Nhan Chinh area within the network of Hanoi City with red and yellow colors represent the highest and the lowest integration, respectively. We can see that the highest integration values are observed mostly near main streets (high and medium level). Meanwhile, the lower integration values are observed around branch streets in the residential area.

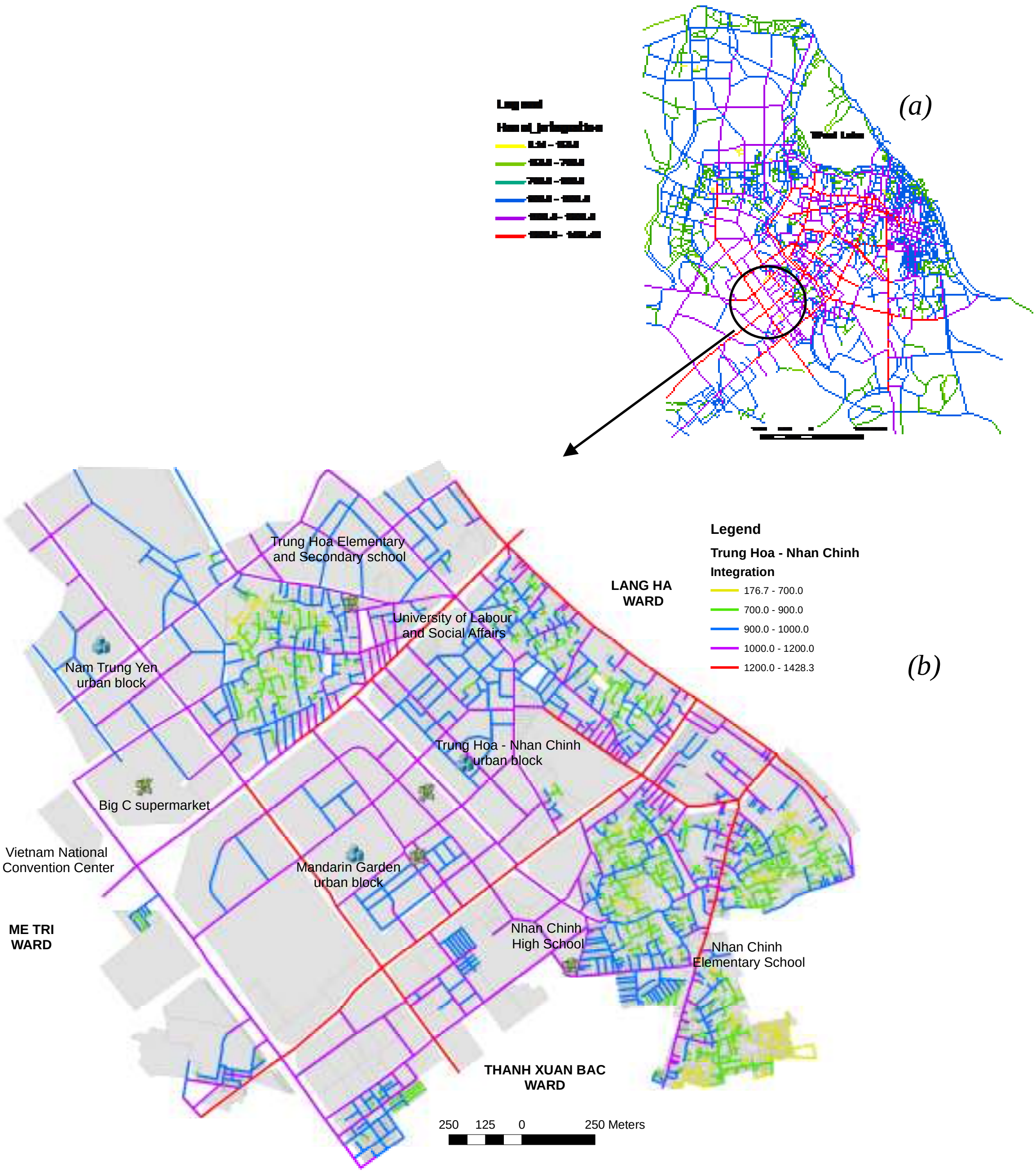

Figure 9. Integration values of street network in Hanoi City (9a)
and in Trung Hoa – Nhan Chinh area (9b)

Table 3 shows statistics of integration values of Trung Hoa – Nhan Chinh area in comparison with those data of Hanoi City. Comparing the relative position of Trung Hoa – Nhan Chinh area to Hanoi City, Trung Hoa – Nhan Chinh area is surrounding by streets with high value of global integration. According to Table 3, the highest integration value in Trung Hoa – Nhan Chinh is 1428.3, which is comparable to the highest value of Hanoi City. As such, we can consider this area as one of centers of Hanoi City.

Table 3. Statistics of the integration value

Measures	Minimum	Maximum	Mean	Standard Deviation
Integration value of Trung Hoa – Nhan Chinh area	176.7	1428.3	1136.04	98.97
Integration value of urban districts of Hanoi City	3.14	1458.4	1006.72	196.79

5.3. Correlation analysis

Correlation analysis was conducted by using SPSS software. The result of correlation analysis is shown in Figure 10. In this study, the Pearson coefficient is used to filter the factors that are closely correlated to urban residential land price. This value is computed by dividing the covariance of the two variables with their standard deviation. In order for this coefficient to be statistically significant, the significant value of the Pearson test must be less than 0.05, equivalent to level of reliability more than 95%.

		Land_ price	D_Urban	D_Hospital	D_School	D_Market	Location	Rank_ street	D_Park	Connectivity	Integration
Land_Price	Pearson Correlation	1	-.378**	-.005	-.051	-.144	-.506**	-.533**	-.116	.253*	.435**
	Sig. (2-tailed)		.001	.967	.662	.213	.000	.000	.320	.027	.000
	N	76	76	76	76	76	76	76	76	76	76

Figure 10. The result of correlation analysis

Figure 10 shows the result of correlation analysis, from which we can identify five of the nine factors that significantly affect on residential land price in the study area: 1) ranking of street, 2) location of land parcel, 3) integration, 4) distance to urban blocks, and 5) connectivity. Four factors have significant value at the 0.01 level, and one factor (connectivity) has significant value at the 0.05 level. Ranking of street and location of land parcel factors have a negative impact on the value of land. Meaning that the land prices at the 1st rank of streets and the 1st location are more expensive than others. In fact, this is quite appropriate for Trung Hoa – Nhan Chinh area because in the State price table, it also shows that land prices in type 1 streets and the 1st location are particularly higher. For example, Table 4 shows the State land price table at some streets in Trung Hoa – Nhan Chinh area.

In addition, distance to urban blocks factor has also a negative sign. This indicates that the more land parcels close to urban blocks, the higher the price is. Integration and connectivity factor have expected positive sign. It means higher values of these variables are associated with higher land price.

Table 4. Illustration of the State land price in Trung Hoa – Nhan Chinh area (Unit: 1000 VND/ m^2) (People's Committee of Hanoi, 2014)

Name of street	Rank of street	1st location	2nd location	3rd location	4th location
Tran Duy Hung	1	48 000	24 960	20 160	17 760
Hoang Dao Thuy	2	37 000	19 980	16 280	14 430

6. CONCLUSION AND FUTURE RESEARCH

In this study, the authors have analyzed the correlation between accessibility factors and urban residential land values in Trung Hoa – Nhan Chinh, Hanoi City. This study identified five factors which have major effects on urban residential land price: 1) ranking of street, 2) location of land parcel, 3) integration, 4) distance to urban blocks, and 5) connectivity. Among them, integration factor showed the degree of center of space. Therefore, it could be used as one of the criteria in order to determine status poles in the multi-polar city (the highest points of social desire or the most attractive poles).

Since the scope of this study was limited to the small area, hence, the influence of the status poles on land parcels may be quite similar. If the research would be done in a larger scale, with the bigger samples, the range of influence of the status poles would be clearer. And therefore, the applications of SQTO theory could be applied effectively. This research is also a supplement to support SQTO in identifying status poles.

Despite of such limitation, this study offered a possibility of integrating different approaches including space syntax, which assesses factors affecting urban residential land values. This study could be improved by increasing the bigger samples and it contributes the further studies in urban planning, land valuation.

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