Short Paper

Ref 125

Natural Movement Versus Land Value

An analysis of the relationship between spatial integration and land value in an Asian City

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Abstract
The basic concept behind space syntax is that a built environment can be divided into interconnected individual spaces or spatial components. The network of spaces can then be analyzed through some measures such as connectivity, integration, choices in way-finding, etc. Through those spatial network analysis techniques defined by the space syntax methodology, one can infer the correlation between spatial layouts and social effects such as crime, traffic flow, sales per unit area, and so on.

Theories of space syntax have stated that in a spatial network, components with higher degree of integration tend to correlate with fewer crimes, higher traffic flow, and higher sales per unit area. This paper follows the aforementioned theories and intends to explore the correlation between spatial integration and land value among components in an urban settlement. This paper assumes that in a spatial network highly integrated components have easier navigability that means better accessibility and probably higher traffic flow. In spaces zoned for commercial use, higher pedestrian traffic flow will usually bring more sales per unit area. When a space can produce more sales than other equivalent spaces, it is reasonable to assume that higher land price or rent can be sustained on the real estate market. Even in spaces not zoned for commercial uses, people normally view better accessibility as an asset and land value would reflect people's rational expectation.

To prove the above hypothesis, this paper uses Taichung City, Taiwan, as the study area to perform the study in the following three steps. First, axial lines of the street network in the major urbanized area of Taichung City are identified and their integration values are calculated. Second, average public assessed land values and other relevant attributes, such as allowed floor area ratio, around midpoints of the axial lines are collected and mapped. Third, hedonic regression analyses are conducted using the average public assessed land value as the response variable and integration values as well as other relevant attributes as predictor variables. The result shows that in the entire major urbanized area encompassing a few heterogeneous neighborhoods, although the local integration is not the most effective predictor variable, it is still a significant one. In short, degree of integration is indeed a significant predictor variable in explaining land value variation in urban settlements.

1. Introduction

1.1 Motivation

Urban settlements are areas of land with high population concentration. Taking a morphological approach, space syntax is an effective analytical theory and tool for understanding, predicting, or explaining urban patterns or emergent behavior in urban settlements (SSS7 Organizing Committee). In essence, the space syntax theory views urban settlements as inter-connected spatial components and uses the degree of integration or segregation of components to depict the spatial pattern of urban settlements (Hillier and Vaughan 2007).

Unlike space syntax, urban economic theories view urban settlements either as the setting where economic activities, such as production, exchange, distribution, and consumption, take place or as the subject of economic activities, *i.e.* goods or services. From these perspectives, the spatial distribution of the value of individual parcels of land in an urban settlement can be seen as another facet of the spatial pattern of that urban settlement.

In space syntax the measure of integration or segregation is one of the key elements in analyzing urban patterns. In urban economics the value of land is also one of the key elements in analyzing urban patterns. If both integration measure and land value are pivotal tools for examining the underlying spatial structure of urban settlements, what would be the relationship between integration measure and land value?

1.2 Space syntax

The basic idea behind space syntax is that it identifies the spatial configuration of a study area as a network, where nodes represent spatial components or "spaces" and links represent connections between spatial components (Wang and Liao 2006). Through this approach we can then treat the analysis of spatial configuration as the well-established network analysis problem.

In an urban settlement consisting of mostly streets, the most obvious "spaces" would be those (preferably longest) straight sections of streets that is visible from one end to the other without obstruction. Hillier (1996) developed the technique of representing those individual "axial spaces" as straight sight-lines, which also represents a possible path of movement, over a map of an urban settlement and called such a drawing an axial map. To measure the degree of integration or segregation in an urban settlement, we calculate the total amount of intersections or "turns" one would encounter when he/she takes the shortest paths to travel from an axial space to all other axial spaces (Wikipedia contributors a). In space syntax terminology, such a measure is called global integration and is denoted by R_n, as the measure is up to radius "n." In addition to global integration, space syntax also defines the measurement of local integration. For instance, the local integration measure of radius 3 only calculates the total amount of turns one would encounter when he/she take the shortest paths to travel from an axial space to only those axial spaces that are up to 2 turns away from himself/herself. Such a local integration measure would be denoted by R_3.

Those axial spaces that have fewer amount of turns to reach all other axial spaces mean they are more accessible and cognitively more intelligible than those with more amount of turns in the axial map (Penn 2003). In space syntax terminology, more accessibility means a higher degree of integration.

1.3 Land value

There are many types of land value. Market value is the type of value most people refer to when they encounter the notion of land value, therefore it is the type of land value we imply in this paper. According to International Valuation Standards, market value is "the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arms-length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently, and without compulsion (IVSC 2007)."

Using the hedonic analysis, which decomposes the item being researched into its constituent characteristics and obtains estimates of the contributory value of each characteristic (Wikipedia contributors b), Peiser (1987, 342) explained land value through the impact of various site, location, neighborhood, and macroeconomic characteristics. He further categorized those characteristics and variables into six general groups and empirically constructed a hedonic model through regression analysis, as follow.

$$V_{xt} = f(C_x, D_x, L_x, E_x, N_x, M_t)$$

where

V_{xt} = sales price of parcel (x) at time (t)
C_x = physical site characteristics (size, slope, trees, soils, etc.)
D_x = macrolocation variables (location with respect to CBD and other major structural features such as suburban nodes)
L_x = microlocation variables (size of street, location on block)
E_x = development expectation (land use and density)
N_x = neighborhood characteristics (income, median rent, education, race, etc.)
M_t = current macroeconomic and financial conditions (health of economy, interest rates).

1.4 Objectives

Among those determinants of land value identified by Peiser (*ibid*), the two groups of locational determinants are the ones relevant to the integration measures of the space syntax. Intuitively, those macrolocation variables should have some relationship with the global integration while those microlocation variables may be connected to the local integration. Therefore, we set the objectives of this study as follow.

a) Examine the relationship between the integration measures and the land value of the study area.
b) Explore other variables that might also affect the land value and their relationship with integration measures.
c) Model the relationship among variables using regression analysis.

2. Methods

2.1 Study area

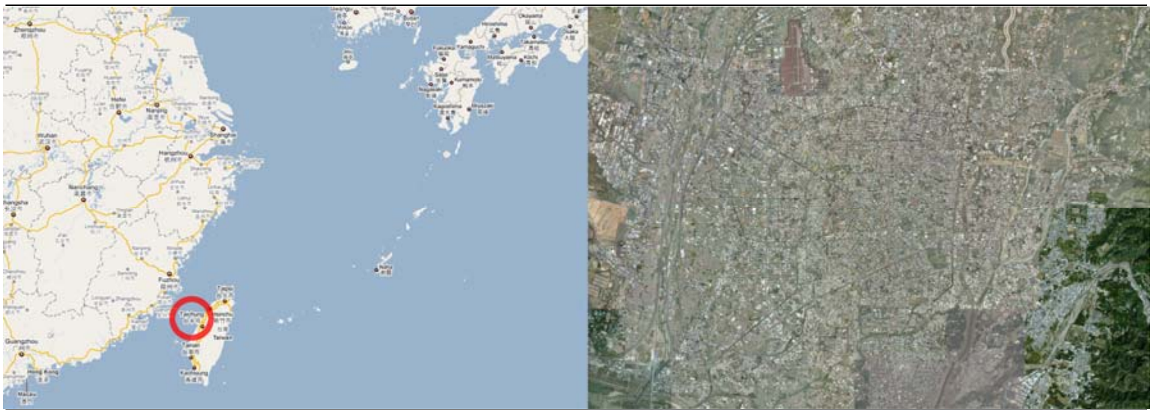

Figure 1
– Geographic location and satellite imagery of Taichung City. (courtesy of Google Map)

The study area is the major urbanized area within the boundary of Taichung City, Taiwan. The left panel of Figure 1 shows the geographic location of Taichung City (marked by the red circle in the figure). A satellite imagery such as the one shown in the right panel of Figure 1, clearly depicts the urban form of Taichung City. The study is executed in three major steps as described below.

2.2 Space syntax analysis

The methods of performing the space syntax analysis include:

a) Create an axial map of the study area by identifying the axial spaces and drawing the axial lines over an official topographical map at the scale of 1/1000.
b) Calculate various measures of axial analysis using the spatial analysis software UCL DepthMap (Space Syntax Laboratory).

2.3 Sampling data acquisition

The axial lines drawn are over 9,300. It is more practical using only a sample of axial lines to extract corresponding information related to land value determinants. The tabulated text output from the DepthMap session is first imported into the spreadsheet program Microsoft Excel. The Excel's built-in pseudo-random function *RAND()* is then used to randomly select axial-line samples from the axial map.

For those randomly selected axial-line samples, their midpoints are identified on the axial map. Circles with a radius of 100*m* are drawn around those axial-line midpoints. Those circles represent the sites for sampling land value-related information. Considering the reliability and accessibility of the necessary information, we decided only acquiring such locational attributes as name and width of the road or street, name of the administrative district, zoning, average public assessed land value, and floor area ratio (FAR).

All these locational attributes can be directly or indirectly extracted from related central or city government web sites. Specifically, the Urban Planning Geographic Information Querying System web site provided by the Urban Development Bureau of the Taichung City government is used to query the road or street width, zoning, and FAR of each sampling sites (Taichung City Government a). In addition, it is necessary to query both the Cadastral Survey Data Querying and Application System (National Land Surveying and Mapping Center) and the Online Land Economy Service of Taichung City (Taichung City Government b) websites to obtain the public assessed land value for all parcels. Finally, because the midpoint of an axial line usually lies on a road or street, we take the simple mathematical average of various numeric location attributes that fall within the 100*m*-radius sampling circle of a sampling site.

2.4 Regression analysis

In this step a regular (stepwise) linear regression is performed. Only those location attributes that are numeric are considered. The response variable is the average public assessed land value (*APA_Value*). The predictor variables are local integration (*R3*), global integration (*RN*), floor area ratio (*FAR*), and width of road (*Road_Width*). In other words, a quasi-hedonic model explaining the average public assessed land value taking the following form is going to be created, tested, and analyzed.

$$\text{APA\_Value} = f(\text{RN, R3, FAR, Road\_Width})$$

R, a free software environment for statistical computing and graphics (Hornik 2008), is the tool for the regression analysis.

3. Results

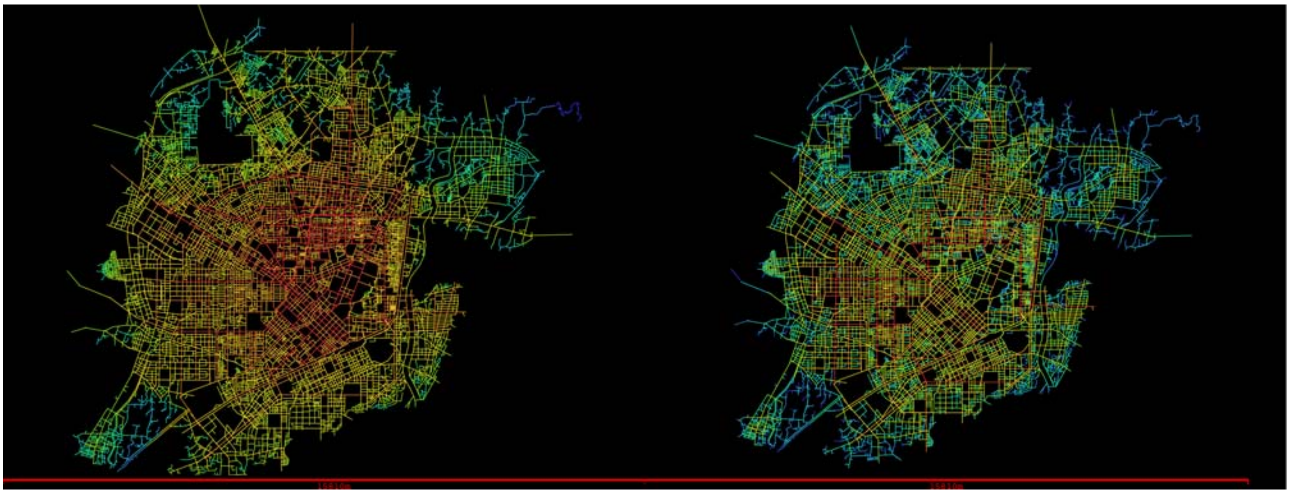

Figure 2
Global and local integrations of the major urbanized area

Figure 2 shows the result of the space syntax analysis. The left panel and the right panel of Figure 2 depict the spatial distribution of the global (*RN*) and local (*R3*) integration of the axial spaces in the study area, respectively.

Using histograms and quantile-quantile plots (Q-Q plots) to check the fulfillment of the normality assumption required by the least-square method in linear regression, we found that among the five variables, *APA_Value*, *FAR*, and *Road_Width* are not normally distributed and require some transformation. After a few trial-and-error, we decided to apply natural logarithms to these three variables. Although they are still not perfectly normally distributed, the least-square linear regression is known to be robust enough to produce acceptable results, even if some of the assumptions are not met (Lourival et al 2008, 25). Figure 3 shows the histograms and Q-Q plots of the initial five variables that will be used in the regression analysis. Note that the three transformed variables are now denoted by *APAP_log*, *FAR_log*, and *RW_log*. Correlation coefficients of these five variables, as shown in Table 1, reveal high correlation between *R3* and *RN*, which indicates that they should not be included in the regression model at the same time.

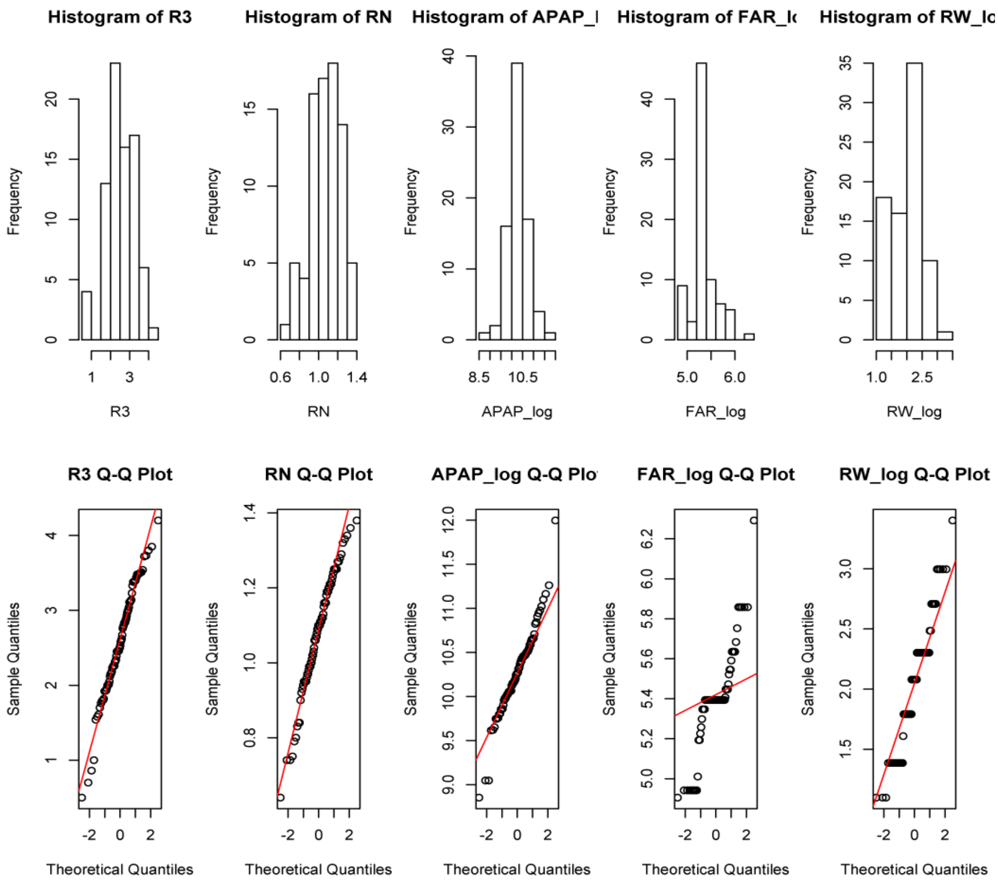

Figure 3
Histograms and Q-Q plots of the initial regression variables.

	R3	RN	APAP_log	FAR_log	RW_log
R3	1.00000000	0.7814579	0.4123631	0.09310218	0.4271525
RN	0.78145793	1.0000000	0.4927228	0.30029188	0.3220207
APAP_log	0.41236308	0.4927228	1.0000000	0.60385285	0.4024590
FAR_log	0.09310218	0.3002919	0.6038529	1.00000000	0.1321140
RW_log	0.42715251	0.3220207	0.4024590	0.13211395	1.0000000

Table 1
Correlation coefficients of the five initial regression variables.

Call:
lm(formula = APAP_log ~ R3 + FAR_log + RW_log)

Residuals:				
Min	1Q	Median	3Q	Max
-1.29414	-0.19088	-0.04013	0.16726	1.10852

Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.42489	0.85785	3.992	0.000150 ***
R3	0.17490	0.05651	3.095	0.002757 **
FAR_log	1.10885	0.15999	6.931	1.18e-09 ***
RW_log	0.20383	0.08304	2.455	0.016389 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3403 on 76 degrees of freedom
Multiple R-squared: 0.5299, Adjusted R-squared: 0.5113
F-statistic: 28.55 on 3 and 76 DF, p-value: 1.812e-12

Table 2
Summary of the final linear regression model.

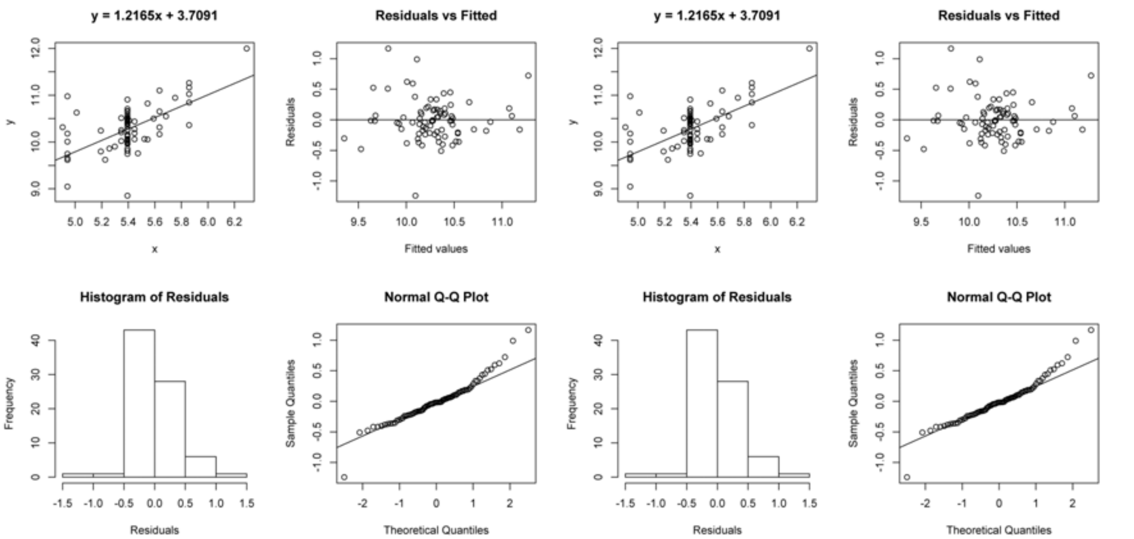

Figure 4
Diagnostic plots for the final regression model.

Table 2 summarizes the final linear regression model with confidence interval at 95% level, after 2 runs of stepwise regression that drop only *RN*. Figure 4 shows four diagnostic plots of the final regression model. Note that because a regular two dimensional plot is not capable of depicting all four variables of the final model at once, only the scatter plot of *APAP_log* versus *FAR_log* with the fitted regression line is shown in the upper left panel of Figure 4. The model can be specified as follows.

APAP_log = 0.1749*R3 + 1.10885*FAR_log + 0.20383*RW_log + 3.42489

Together the three predictor variables, *R3*, *FAR_log*, and *RW_log*, explain over 50% of the variance in *APAP_log*. Individually, however, *FAR_log* explains nearly 35% of the *APAP_log* variance and *R3* explains only about 15% of the variance. *RW_log* explains an even smaller portion that could be thought as negligible. This result coincides with previous studies that also attempted to clarify the correlation between integration and land value (Min et al 2006). This finding is significant in that the assertion of spatial integration being an effective explanatory or predictor variable for land value seems to uphold even across cultural and national boundaries.

4. Discussion

The spatial distribution of the local integration, as shown in the right panel of Figure 2, suggests that there exists several relatively homogeneous neighborhoods, possibly delineated by those smaller grids of different bearings, in the study area. Therefore, when the study area is large enough to encompass several such neighborhoods, it is the local integration that is more suitable to explains the relatively smaller land value variation in individual neighborhoods within the larger and heterogeneous study area.

In other words, when the study area encompasses both the rampant fringes and the static core of the Taichung City, a larger amount of people will give more weight to future economic returns from the land than the land's current accessibility when they try to value a parcel. Therefore, those variables related to development expectation prevail in the land valuation equation. For instance, in the regression model the most significant variable *FAR_log* is directly related to the density in terms of floor area that one can build on top of his/her parcel and either sell or rent for money. Besides, due to the fact that a wider road can usually carry more traffic, it is a reasonable practice in Taiwan for urban planning authorities to designate more intense type of land use, such as commercial or high density residential districts, to parcels in the close vicinity of wider roads. Given the more profitable zoning designation, it is not surprising that *RW_log* is included as a significant predictor variable in the regression model.

5. Conclusion

This paper discusses a study that uses the urbanized area of Taichung City to examine the relationship between the degree of integration and land value in an urban settlement. The study is performed in three steps, space syntax analysis, sampling data acquisition, and regression analysis, in respective order. The result shows that although local integration is a significant predictor variable in the regression model, it is not the most effective one. Among three final predictor variables, floor area ratio turns to be the best one in explaining land value variation in the study area.

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