The effect of accessibility on retail rents: testing integration value as a measure of geographic location

Olof Netzell

Building and Real Estate Economics

Royal Institute of Technology

Stockholm 2010

The effect of accessibility on retail rents: testing integration value as a measure of geographic location

Abstract: This paper tests whether *integration value*, a measure of geographic location, can help explain retail rents. The hypothesis is tested on data from Downtown Stockholm. A statistically significant effect of integration value on retail rent is found. The integration value, developed within the research field Space Syntax, can be understood as a measure of the accessibility of a certain location in a street network. The measure is constructed using tools from graph theory and uses the shape of the street network as its only input.

Introduction

This paper tests whether *integration value* – which may be understood as a measure of the accessibility of a location - can help explain the geographic distribution of retail rents in a metropolitan area. It thus tries to explain why the retail rent in a particular street segment A is different from that in street segment B.

Location is a central concept to several strands of the retailing literature. Consumer store choice models and store location models are obvious examples. Optimal store location typically depends on the location of competing stores and consumers while consumer store choice models typically assume that consumers prefer the closest store ceteris paribus (Vandell and Carter (1993) review earlier literature in this area, Drezner et al. (2002), Dellaert et al. (2008) and Popkowski Leszczyc et al. (2004) are examples of recent references). In this literature, the concept ”location” is typically tied to the distance to important locations. The integration value may be viewed as a refinement or complement to traditional notions of distance such as metric distance.

The integration value was developed within the research field Space Syntax and is intended to describe how well integrated – or accessible - a location is in a metropolitan area. The measure is constructed using tools from graph theory and uses the shape of the street network as its only input. It has been found to be correlated with a number of human activities such as different types of traffic, crime etc and, importantly for this study, it has been found to be correlated to pedestrian movement (Enström and Netzell (2008) list examples of this literature).

The primary purpose of this paper is to test whether there is a statistical relationship between integration values and retail rents controlling for a number of other relevant factors. This idea is tested on data from Downtown Stockholm. On a broader level, an important purpose is to introduce the ideas of Space Syntax in the retailing literature.

The first section of the paper introduces Space Syntax and describes the integration value. The second section describes the theoretical framework regarding retail rents and accessibility. The third section describes the nature of the data that has been gathered and describes the control variables used in the empirical analysis. The fourth section describes the results of the empirical analysis and the last section concludes the study.

Space Syntax

Space Syntax may be described as a set of theories and techniques for analysing the built environment - or more generally space - using a quantitative approach. The purpose is to explain and predict the outcomes in terms of some aspect of human behaviour of a particular design. To exemplify, the aim may be to predict which path people typically will take through a planned building or which streets in an urban grid that will have the highest number of pedestrians. The general approach is to divide the space under study into components using a set of rules and then measure certain spatial and topological characteristics of the components. References that give a thorough description of the basic ideas include Hillier and Hanson (1984), Hillier (1996) and Hanson (1998).

This study uses a particular type of analysis developed within Space Syntax which is described for instance in Hillier and Hanson (1984) and Teklenburg et al. (1993). The output of the analysis is a graph-mathematical representation of a metropolitan area. Using the graph one can calculate integration values for the subspaces of the metropolitan area. A more exact description of what is meant by subspace will follow but one may roughly think of them as street segments. Integration values are intended to measure how well integrated the subspaces, or street segments, are in the metropolitan area.

The analysis starts with a digital map of the area. Based on the digital map, an axial map is created. This involves several steps. First, the map of the metropolitan area is divided into public and non-public space. The public space is subsequently covered with so called convex spaces. Convex spaces are two-dimensional objects for which a straight line connecting any pair of points within the object is also within the object. Intuitively, a convex space is such that one can see every point in the space from every point in the space. The public space of the metropolitan area under study is covered with as few convex spaces as possible. The map of convex spaces is called a convex map. The convex map is converted into an axial map by drawing straight lines that cross each convex space in the convex map. The straight lines - so called axial lines - should be as few as possible and may be interpreted as sightlines. Figure 1 shows a map of parts of London and the corresponding axial map.

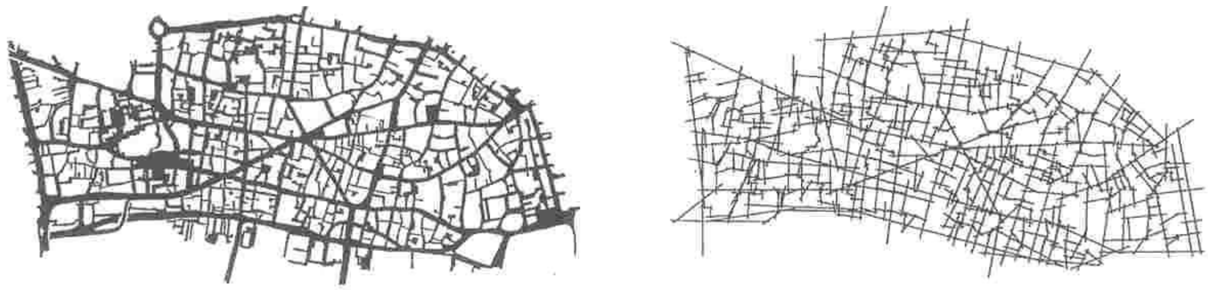

Figure 1. (Hillier 1996) The panel to the left shows a map of parts of London and the panel to the right shows the corresponding axial map.

An axial map may be viewed as a graph where the axial lines are represented as nodes. If two axial lines intersect the corresponding nodes are connected. Figure 2 illustrates how an axial map may be seen as a graph. Representing a metropolitan area as a graph allows quantitative analysis of how the public subspaces of the area are connected. One may for instance measure the topological distance between two nodes, i.e. the minimum number of steps one has to take to go from node i to node j. This measure is called depth, d_{ij}. The depth between two street segments that intersect is one. Since the nodes in the graph represent street segments the depth may be interpreted as one (1) plus the minimum number of street segments one must pass to go from one street segment to another. Furthermore, given that the axial map consists of straight sightlines one may interpret depth as the minimum number of turns that a pedestrian must make to walk from one node to reach another node.

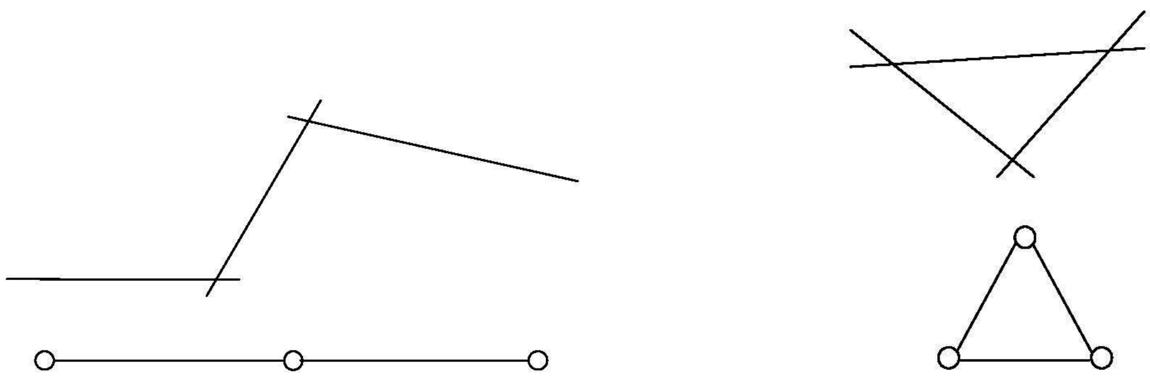

Figure 2. (Enström and Netzell 2008) The figure shows two axial maps and their corresponding graphs.

The total depth of node *i* is the sum of the depths to all other nodes in the graph:

$$D_i = \sum_{j=1, j\neq i}^{L-1} d_{ij} \qquad (1)$$

L represents the number of nodes in the graph (also referred to as the size of the graph). Mean depth is defined as total depth divided by *L* minus one:

$$\overline{D}_i = \frac{D_i}{L-1} \qquad (2)$$

Mean depth may be interpreted as the average number of turns that a pedestrian must make to go from one street segment to other street segments in the network.

Two types of standardization of mean depth are applied in order to calculate the integration value of a node. The first, relative asymmetry, RA_i, relates mean depth to its theoretical maximum, $\overline{D}_i^{\max}$, and its theoretical minimum, $\overline{D}_i^{\min}$, and results in a measure that is limited to the interval zero and one. The lowest possible mean depth for a node is one (1) and occurs when the node is adjacent to all other nodes. It can easily be shown that $\overline{D}_i^{\max} = L/2$ (Enström and Netzell 2008). RA_i is defined as

$$RA_i = \frac{2(\overline{D}_i - 1)}{L-2}. \qquad (3)$$

RA_i is the ratio of the difference between the mean depth of node *i* and its theoretical minimum mean depth to the difference between the theoretical maximum mean depth and its theoretical minimum mean depth.

RA_i depends on the size of the graph. The second type of standardization which results in the measure real relative asymmetry, RRA_i, is intended to reduce the effect of size by dividing RA_i with the relative asymmetry of a standardized node in a standardized graph. RA_i is thus divided by the relative asymmetry RA^D of the so called ”root” node of a diamond-shaped graph of the same size as node *i*’s graph (Hillier and Hanson 1984; Teklenburg et al. 1993):

$$RRA_i = \frac{RA_i}{RA^D} \qquad (4)$$

Integration value is defined as the inverse of RRA_i

$$Integration\ value = \frac{1}{RRA_i} \qquad (5)$$

A greater integration value signifies a street segment that is highly integrated in the urban area. In the Space Syntax literature integration values are believed to be a potential determinant of human movement patterns and other human behaviour. There is no explicit rigorous theory supporting this idea. It rests on intuitive arguments and the empirical support that has been found (Enström and Netzell (2008) give examples of studies and research settings where Space Syntax techniques have been applied and the studies that are most relevant for this paper are briefly described below). Penn (2003) discusses a potential underlying theory. He suggests that integration values capture how people cognitively perceive and process space. He argues that perhaps our understanding of space is not only metric, as implicitly assumed in the monocentric model for instance, but also topological. A concrete effect of this could be that making turns is costly since this roughly corresponds to moving from one topological space to another. As the integration value may be seen as a standardized measure of how many turns are needed to move from a node, or street segment, to other nodes this could explain a relationship between integration values and human activity (movement patterns in particular).

One important aspect of the calculation of integration values remains; the distinction between *local* and *global* integration value. Let us think of the subgraph *S* of the total graph of the urban area under study. *S* consists of node *i* and the nodes *within* three steps from node *i*. We may calculate the integration value for node *i* in subgraph *S*. D_i is then the total depth to nodes in *S*, *L* is the number of nodes in *S* and RA^D is the relative asymmetry of the root node of a graph of the same size as *S*. The integration value thus calculated is referred to as a local integration value of node *i*. Similarly we may calculate the local integration value for node *j* which is based on the subgraph including node *j* and the nodes within three steps of node *j*. Integration values calculated using the complete graph of the urban area is referred to as global integration values. As the names indicate, local integration values are intended to measure a more local characteristic of a node than the global integration value.

As mentioned above, empirical support for the idea that integration values are relevant for explaining human activity has been found in a number of studies. The link between integration values and pedestrian traffic has been investigated in Hillier et al. (1983), Hillier et al. (1987), Hillier et al. (1993), Hillier and Hanson (1984), Hillier (1988), Peponis et al. (1989) and Marcus (2000). This research finds a correlation in many circumstances mainly to local integration value. Marcus (2000) finds correlation between integration values and pedestrian traffic in downtown Stockholm. Enström and Netzell (2008) and Netzell (2003) examine whether integration values can explain office rents in central Stockholm. A statistically significant relationship is found between global integration values and spatial distribution of office rents. Desyllas (1999) investigates Berlin office rents and finds correlation between integration values and office rents. Hossain (1999) examines how location of Dhaka commerce covaries with integration values and finds a strong correlation. Kim and Sohn (2002) find strong correlation between integration values and land use density of office buildings. To the best of my knowledge there are no previous studies of retail rents and integration values.

The relationship between retail rent and accessibility

Consumers are assumed to prefer shops that are easily accessible. Thus, shops that are more accessible will get more customers. Assuming that higher number of customers leads to higher sales, competition for accessible locations should drive up rents for shops that are accessible. Accessibility may be measured in several ways. Building on the description of the Space Syntax literature in the previous section it is hypothesized that local integration value is an important measure of accessibility.

***Hypothesis*.** Local integration value positively impacts retail rent in a metropolitan area.

There are however other measures of the accessibility of a location. In the monocentric model for instance, distance to the CBD or city center may be seen as an accessibility measure. Urban economists have also studied polycentric urban structure (several focal points). See Anas et al. (1998) for an overview of research on urban spatial structure.

The relation between integration value as a measure of accessibility and other accessibility measures is important for the present study. Integration value captures a particular aspect of accessibility. It is therefore plausible that it should be seen more as a complement to other measures of accessibility rather than a complete measure of accessibility in itself. Furthermore, integration value may be correlated to other measures of accessibility. Failure to control for these other measures would lead to a risk of false conclusions regarding the effect of integration value. To completely control for this possibility is virtually impossible. One can neither be certain that an accessibility measure is perfect in the sense that it captures all variation due to accessibility nor that it is the ”true” measure in the sense that it is derived from the true mechanisms behind accessibility (assuming that accessibility is in fact a relevant factor). One should however be able to argue that a proposed new measure adds to existing knowledge. In order to do this, the present study should at least include distance to the city center. The study also controls for multiple centers and differences in accessibility across city parts. Thus, accessibility as explanatory variable for retail rents is captured with local integration value, the metric distance (as the crow flies) to the city center as well as other focal points and city part dummies.

Given certain assumptions regarding preferences, technology and other factors, the monocentric model predicts a (negative) exponential land rent function (Anas et al. 1998). The exponential function is also common in empirical studies (Söderberg and Janssen 2001) and studies that investigate rent in polycentric areas also commonly use some generalization of the exponential function (Anas et al. 1998). Regarding the integration value, theory offers less guidance. A flexible functional form, translog, will therefore be employed for the integration value. The model:

$$Rentsqm = \alpha e^{\beta Distance} Integration^{\gamma_1} e^{\gamma_2 \ln^2(Integration)} e^{\delta Dcitypart} \qquad (6)$$

Rentsqm is the rent per square meter. In the simplest version of the model *Distance* is the metric distance to the city center. *Distance* can also be a *vector* of distance measures to different focal points in which case β is a row-vector of coefficients. *Dcitypart* is a vector of city part dummies and δ a row-vector of coefficients. *Integration* is local integration value.

In order to estimate the relationship between retail rent and accessibility one would ideally observe rents from contracts that are exactly similar except for the rent and the accessibility of each respective shop. However, observed retail rental contracts typically differ regarding not only the rent and the accessibility of the shop but also characteristics of the shop other than its accessibility, contractual terms and other factors (For instance: Is the contract a renewal of an old contract?). Estimation of the relationship should therefore take these factors into account as well. These factors are described in detail in the data section that follows.

The data

In order to gather a relevant data set on retail rents a questionnaire was sent to 552 shops in the central parts of Stockholm. The questionnaire includes questions regarding the rent, the characteristics of the shop (including location), contractual terms and other factors that may affect the rent. 134 shops replied to the questionnaire. 114 of the replies were used. The rest either had missing data of crucial variables or contained obviously misreported data. Due to the low reply rate selection bias cannot be ruled out. There is however no obvious reason to suspect that the selection bias is related to integration values. Hence, selection bias does not a priori seem to be a major problem for the main purpose of the study. Table 1 presents variable definitions.

Table 1 Variable definitions

Name	Variable definition
Rentsqm	Total current rent (excluding VAT) divided by total area in square meters.
Distance	Distance to Sergels torg.
Integration	Local integration value at the location of the shop
Dsoder	Dummy-variable. Equals 1 if the shop is located in the city part Södermalm, 0 otherwise.
Doster	Dummy-variable. Equals 1 if the shop is located in the city part Östermalm, 0 otherwise.
Dkungsh	Dummy-variable. Equals 1 if the shop is located in the city part Kungsholmen, 0 otherwise.
Dgamla	Dummy-variable. Equals 1 if the shop is located in the city part Gamla Stan, 0 otherwise.
Dnorrm	Dummy-variable. Equals 1 if the shop is located in the city part Norrmalm, 0 otherwise.
Dvasa	Dummy-variable. Equals 1 if the shop is located in the city part Vasastan, 0 otherwise.
Area	total area in square meters
Floorratio	Shop area divided by total area (total area may include storage and office area)
Dmall	Dummy-variable. *Dmall* =1 if the shop is located in a mall, 0 otherwise.
Dnotstreet	Dummy-variable. *Dnotstreet* = 1 if the shop is not located on street level, 0 otherwise
Ddiscount	Dummy-variable. *Ddiscount*=1 if there is a discount on the rent for parts of the rental period, 0 otherwise.
Dnotindex	Dummy-variable. *Dnotindex* =1 if the rent is *not* indexed, 0 if it is indexed.
Dturnover	Dummy-variable. *Dturnover* =1 if the rent is based on turnover, 0 otherwise.
Dnewshop	Dummy-variable. *Dnewshop*=1 if the shop is newly established, 0 otherwise.
Dtax	Dummy-variable. *Dtax*=1 if property tax is included in the rent, 0 if tax is paid separately.

Apart from the dependent variable and accessibility measures, table 1 includes a number of control variables. The first set of variables capture characteristics of the shop other than its location and may be seen as hedonic variables:

- It is assumed that there are economies of scale in supplying retail space and hence it is expected that the size of the shop is negatively related to the rent per square meter. *Area* enters the model in multiplicative form.
- The floor space of a shop may consist partly of office area and storage area. These types of floor space typically have a lower rent. The rent per square meter for a shop should thus be affected by the relative amounts of different types of floor space. *Floorratio* is expected to have a positive coefficient and enters the model in exponential form.
- Being located in a mall likely constitutes a positive externality for a shop. The vicinity to other shops may lead to more people passing by and thereby more potential customers. In essence, there are agglomeration economies associated with a mall. Hence it is expected that shops located in malls typically have higher rents.
- Not being located on street level lowers the advertising value of a shop which should lead to lower rent for such shops.

The latter set of control variables in table 1 captures contractual terms and other factors:

- *Ddiscount* is a dummy variable for contracts that have or have had a rent discount. In the studied data the discount decreases during the contractual period for all shops that have or have had a rent discount. It is also the case that the majority of these shops no longer have any rent discount. The discount applied during earlier years of the contractual term. It is assumed that landlords compensate themselves for discounts during the first period of the contract by a rent which is higher than ”normal” (that is, a contract without discounts) towards the end of the contract term. If this is the case we should expect a positive sign for the dummy *Ddiscount*.
- Some retail rental contracts have indexed rents (the rent follows inflation). All else equal, at the time the contract is signed a contract in which the rent is indexed should be lower than if the contract is not indexed, assuming positive inflation expectations. After the contract is signed the effect of indexation depends also on the actual inflation development compared to expectations, and

at what point in time the rent is observed relative to when the contract was signed. *Dnotindex* is a dummy that controls for differences between contracts with and without indexation clauses.

- For the tenant, a turnover-based rent can be seen as a type of insurance (matching of income and cost). Therefore it is expected that rent based on turnover typically is higher. A positive sign is expected for the dummy variable *Dturnover*.
- Due to imperfect information the landlord is exposed to more risk when negotiating a rental contract with a new tenant compared to a sitting tenant. Assuming that landlords demand compensation for this higher risk a positive sign should be expected for the dummy variable *Dnewshop*.
- Property owners pay property tax which is proportional to the property value. This cost is transferred to tenants. In some contracts, the property tax is included in the rent while some landlords prefer to charge the property tax separately. The rent is expected to be higher if tax is included than if it is paid separately. Hence, a positive sign is expected for *Dtax*.

All variables that control for contractual terms and other factors are dummy variables. The chosen functional form means that the coefficients for the dummy variables are interpreted as percentage changes. This makes sense from an economic point of view since this means that the change in rent is proportional and not absolute. To exemplify one may note that the property tax is a percentage of the property value. The rent is likely to be roughly proportional to the property value. Thus, the property tax paid by the tenant should be roughly proportional to the rent per square meter. Thus the functional form should allow a proportional difference between contracts that include property tax and those that do not. Similar arguments are valid for the other dummy control variables.

Table 2 shows descriptive statistics for the variables used in the study and table 3 shows correlations of the variables. The correlations are largely as expected. It is noteworthy that *Integration* and *Distance* are negatively correlated as expected (highly integrated locations, which have high *Integration*, tend to be close to the center, i.e. have low *Distance*). The correlation is however fairly weak, only -0.16. Shops in malls tend to have a turnover-based rent, *Dmall* and *Dturnover* have a correlation coefficient of 0.45.

Table 2. Descriptive statistics. No of observations 114.

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
Rentsqm	2965	2257	12364	532	2179	2.1	7.5
Distance	1103	972	2769	35	715	0.5	2.3
Integration	4.83	4.85	6.15	1.89	0.77	-0.6	3.8
Dsoder	0.19	0	1	0	0.40		
Doster	0.23	0	1	0	0.42		
Dkungsh	0.08	0	1	0	0.27		
Dgamla	0.08	0	1	0	0.27		
Dnorrm	0.30	0	1	0	0.46		
Dvasa	0.12	0	1	0	0.33		
Area	290	141	3140	26	409	4.0	24.0
Floorratio	0.77	0.82	1	0.12	0.22	-0.8	2.8
Dmall	0.09	0	1	0	0.28		
Dnotstreet	0.06	0	1	0	0.24		
Ddiscount	0.10	0	1	0	0.30		
Dnotindex	0.07	0	1	0	0.26		
Dturnover	0.09	0	1	0	0.28		
Dnewshop	0.14	0	1	0	0.35		
Dtax	0.43	0	1	0	0.50		

Table 3 Correlations. No of observations 114.

	Rentsqm	*Distance*	*Integration*	*Area*	*Floorratio*	*Dmall*
Distance	-0,47					
Integration	0,16	-0,16				
Area	-0,18	0,14	-0,18			
Floorratio	0,35	-0,17	-0,13	-0,18		
Dmall	0,66	-0,14	0,04	-0,14	0,25	
Dnotstreet	0,15	-0,10	-0,01	-0,09	0,14	0,31
Ddiscount	0,12	-0,01	-0,13	0,01	0,07	0,11
Dnotindex	-0,13	0,14	-0,06	-0,06	-0,03	0,04
Dturnover	0,44	0,01	0,15	0,13	0,15	0,45
Dnewshop	0,26	-0,16	-0,04	-0,03	0,24	0,05
Dtax	0,00	-0,07	-0,15	-0,11	-0,02	-0,02
Dsoder	-0,21	0,67	-0,15	-0,01	-0,06	-0,07
Doster	0,20	-0,19	-0,03	-0,10	-0,01	0,20
Dkungsh	-0,18	0,19	0,10	0,04	-0,06	-0,09
Dgamla	-0,02	-0,08	-0,20	-0,10	-0,01	-0,09
Dnorrm	0,30	-0,63	0,32	0,07	0,11	0,07
Dvasa	-0,26	0,22	-0,15	0,10	-0,02	-0,12

Table 3 continued Correlations. No of observations 114.

	Dnotstreet	*Ddiscount*	*Dnotindex*	*Dturnover*	*Dnewshop*	*Dtax*
Ddiscount	-0,08					
Dnotindex	0,22	-0,09				
Dturnover	0,18	0,11	-0,09			
Dnewshop	-0,10	0,12	-0,11	0,05		
Dtax	0,07	-0,10	0,25	-0,21	-0,10	
Dsoder	-0,13	0,07	0,04	0,01	-0,07	0,02
Doster	-0,14	0,11	-0,15	0,13	0,02	-0,13
Dkungsh	-0,07	-0,10	0,17	-0,09	-0,02	0,01
Dgamla	-0,07	0,12	0,05	-0,09	-0,12	0,21
Dnorrm	0,15	-0,08	-0,10	0,07	0,18	0,01
Dvasa	0,24	-0,12	0,11	-0,12	-0,07	-0,05

Estimation results

Taking the natural logarithm of model (1) and including the control variables described in the data section we have an equation which is possible to estimate with linear estimation techniques. The model was estimated in three different versions using OLS (*Dvasa* was chosen as the base city part dummy variable). Each version has a different set of distance variables that measure the distance as the crow flies to focal points (the city center and a subcenter). In the first version, *Distance* was calculated assuming that Sergels Torg, commonly viewed as the center of Stockholm, is the center of the city. In their study of distance gradients, Söderberg and Janssen (2001) also assume that Sergels Torg is the city center.

Rather than *assuming* where the city center is located, one may use the data to estimate where the market for retail space appears to place it. This was achieved by varying the location of the city center and running a regression for each assumed location with distance to the "city center" recomputed for each point. The point for which the regression exhibits the highest fit (R^2) may be viewed as the point where the market places the city center.

The inner city was divided into a rectangular grid with limits defined by the outermost shop locations found in the database. The grid had a spacing of 100 meters in both dimensions. The model *without the variable integration* was estimated for each point in the grid. Söderberg and Janssen (2001) use a similar methodology. Using this procedure, the city center is found to be roughly 300 meters to the east of Sergels Torg. The assumed and ”market” centers are thus located fairly close to each other.

The model was also estimated in a version in which a sub-center was allowed. The sub-center was found using a similar methodology as was used when the location of the main center was estimated: the location of the sub-center was varied and a regression was run for each assumed location with distance to the second center recomputed for each point. The model without the variable *Integration* but including the distance to the (*estimated*) main center was estimated for each point in the grid. As pointed out in Anas et al. (1998) it may be unrealistic to assume that the second center has an effect on the whole metropolitan area. It may be more realistic to assume that nearness to the sub-center is important up to a certain distance from the sub-center. Allowing for this possibility was achieved by running the regressions assuming different radiuses of the sub-center. The smallest radius tested was 500 meters, the second smallest 1000 meters, the third 1500 meters and so on with the radius increased by 500 meters for each new set of regressions until the whole metropolitan area was included in the radius. For each radius, the location of the subcenter was re-estimated. That is, the total number of regressions equals the number of possible sub-center locations (the number of points in grid) times the number of different radiuses tested. When the radius was 2000 meters, the fit (R^2) was the highest. There is some variation in which location is found to be the sub-center depending on radius but for most of the radiuses the location coincides with the location found for radius 2000 meters, Hornstull. Hornstull lies southwest of the main city center and can be seen as a micro-sub-center (most observers would argue that the area around Sergels Torg and the estimated main center are quite dominant in the central parts of Stockholm).

The results from the estimations are given in Table 4. For the version with two estimated centers, the results for radius 2000 are reported. The results are largely as expected. Insignificant variables have been dropped. The differences between the three versions are comparatively small. All distance variables are highly significant. If the distance to the center increases by one kilometre it roughly corresponds to a 50 percent fall in the rent. *Integration* is also significant. The hypothesis of this study cannot be rejected. A ten percent increase in integration value roughly corresponds to a five per cent increase of the rent. The effect is stronger in the version for which the location of the center was estimated and weaker in the version in which two centers were estimated.

Table 4

Regression results (OLS, heteroscedasticity-consistent standard errors). 114 Observations.
Dependent variable: log(*Rentsqm*)

	City centre chosen (Sergels Torg)		City center estimated		Two centers estimated	
	Coeff.	*t*-value	Coeff.	*t*-value	Coeff.	*t*-value
Intercept	7,52	14,3***	7,25	15,0***	7,83	17,4***
Distance to Sergels torg/estimated center	-0,00050	-7,6***	-0,00051	-8,0***	-0,00055	-9,0***
Distance to second center					-0,00042	-6,5***
log(*Integration*)	0,52	2,3**	0,66	2,8***	0,41	2,0**
Dsoder	0,29	2,5**	0,30	2,7***	0,57	5,0***
Dkungsh					0,71	4,3***
log(*Area*)	-0,088	-2,2**	-0,075	-1,8*	-0,10	-2,5**
Floorratio	0,43	2,2**	0,46	2,6**	0,36	2,3**
Dmall	0,76	6,6***	0,68	5,9***	0,66	5,4***
Dnotstreet	-0,38	-3,3***	-0,28	-2,8***	-0,25	-2,3**
Ddiscount	0,21	2,5**	0,17	2,0**		
Dturnover	0,48	4,8***	0,46	4,3***	0,46	4,9***
Dnewshop					0,20	1,9*
R^2	0,65		0,69		0,75	
Adj. R^2	0,62		0,66		0,72	
Moran's I test stat (a)	0,15		0,22		0,21	
Moran's I test stat (b)	0,66		0,66		0,66	

(a) Spatial weight matrix: distance-based. Test statistic asymptotically standard normal.
(b) Spatial weight matrix: contagion-based. Test statistic asymptotically standard normal.
* Significant on ten percent level
** Significant on five percent level
*** Significant on one percent level

Area has a statistically significant negative effect suggesting scale economies in providing retail space. A doubling of the area corresponds to roughly ten percent lower rent per square meter. *Floorratio* has a statistically significant positive effect as expected. If the ratio of shop area relative to total area increases by one percentage point it roughly corresponds to a 0.4 percent increase in *Rentsqm*. Several of the dummy variables are also statistically significant. As expected, the rent is higher for shops in malls, for shops with turnover-based rent and for shops that are located on street level. *Ddiscount* is statistically significant for the versions with one center and has the expected positive sign. *Dnewshop* is statistically significant and has the expected positive sign for the version with two centers. Quadratic forms of the variables *Floorratio* and log(*Area*) were tested but found insignificant.

Spatial correlation between observations may be present in the data. For an introduction to spatial econometrics see for instance LeSage and Pace (2004). Morans I was calculated in order to test for spatial correlation (Morans I is described for instance in de Graaff et al. (2006)). Two spatial weight matrices were used. The first spatial weight matrix was based on the metric distance between observations. That is, correlation between observations is assumed to depend on the metric distance between them. The second spatial weight matrix was constructed assuming contagion (correlation) between observations on the same street segment. Morans I was not statistically different from zero for any of the regressions or weighting methods (test statistics are reported in table 4). For the second weighting method, though not statistically significant on conventional levels, Morans I was considerably higher.

In order to test the robustness of the results with respect to correlation between observations located on the same street segment the model was reestimated using data where observations have been averaged over street segments (Wooldridge 2003). This obviously avoids correlation of observations on the same street segment since there only is one observation per street segment after averaging, but it also means that we lose information. Dummy variables, except for city part dummies, were excluded in these regressions. Results from estimation of the three versions on averaged data are given in table 5.

The findings are roughly similar to the findings in the previous regressions but with some notable differences. The effect of distance to the city center and the effect of *Floorratio* is stronger in the averaged regressions. Also, *Area* has a positive sign in the regressions with averaged data. Furthermore, a different secondary center is found in the averaged data than in the estimations on non-averaged data. The findings are however in line with the previous regressions in that the integration value is positive, statistically significant and of roughly similar magnitude. The differences in findings may be due to correlation between explanatory variables and the fact that dummy variables other than city part dummies are excluded in the averaged regressions.

Table 5

Regression results for averaged data (OLS, heteroscedasticity-consistent standard errors). 65 observations.

Dependent variable: log(*Rentsqm*)

	City centre chosen (Sergels Torg)		City center estimated		Two centers estimated	
	Coeff.	*t*-value	Coeff.	*t*-value	Coeff.	*t*-value
Intercept	7,10	15,0***	6,28	9,8***	6,52	10,3***
Distance to Sergels torg/estimated center	-0,00063	-6,3***	-0,00061	-8,5***	-0,00061	-8,6***
Distance to second center					-0,00299	-6,9***
log(*Integration*)	0,51	2,3**	0,67	3,2***	0,61	3,0***
Dsoder	0,37	2,2**	0,29	2,4**	0,24	2,1**
log(*Area*)			0,10	1,7*	0,09	1,8*
Floorratio	0,58	2,3**	0,72	3,0***	0,67	2,7***
R^2	0,51		0,60		0,69	
Adj. R^2	0,48		0,56		0,66	
Moran's I test stat (a)	0,16		0,24		0,28	

(a) Spatial weight matrix: distance-based. Test statistic asymptotically standard normal.

* Significant on ten percent level

** Significant on five percent level

*** Significant on one percent level

Conclusion

This paper tests the hypothesis that the accessibility measure integration value helps explain the difference in retail rent in different locations in a metropolitan area. The integration value may be seen as a refinement of traditional distance measures. The hypothesis cannot be rejected. I have controlled for the distance to focal points such as the city center and for citypart effects. Control variables related to contractual terms, characteristics of the shop other than location and other factors are also included.

Assuming that retail rents are affected by integration value and that locations with high rents *ceteris paribus* can be interpreted as attractive locations we can predict what locations are attractive for establishing a shop. At this point we should remember what data is needed to calculate integration values. A map showing public and non-public space of the metropolitan area under study is enough. Since this can be provided for planned development we could predict what locations in planned development that will be attractive for establishing shops. For already built up areas, locations with high integration values could be seen as locations with potential for shop establishment.

A straightforward extension of this research would be to test the hypothesis on data from other cities. An interesting aspect of such an extension is that integration values may be important in some types of metropolitan area while not in others.

The spatial econometrics aspect of this study may be developed. If spatial topological measures such as integration value are relevant for human activities this may create spatial correlation in data sets of spatial nature. In order to make correct inferences in these circumstances this type of spatial correlation should be considered. In practice, the axial map and topological measures calculated using it may be used in the construction of spatial weight matrices.

Space Syntax techniques have been applied *within* buildings as well. This may be a fruitful research area for retailing since this type of modelling could be applied to movement patterns of customers in a mall for instance (Brown (1999) studies shopping malls using Space Syntax techniques). Such research could potentially be useful when planning the layout of malls etc. There may also be potential for modelling movement patterns *within* a store in which case Space Syntax techniques could be used in decisions regarding the distribution of goods on shelves etc.

References

Anas, A., Arnott, R. & Small, K.A. (1998). "Urban Spatial Structure", *Journal of Economic Literature, 36*(1), 1426-1464.

Brown, M.G. (1999). "Design and value: Spatial form and the economic failure of a mall", *Journal of Real Estate Research*, *17*(2), 189–226.

de Graaff, T., van Montfort, K. & Nijkamp, P. (2006). "Spatial Effects and Non-Linearity in Spatial Regression Models: Simulation Results for Several Misspecification Tests" in *Spatial Dynamics, Networks and Modelling*, Aura Reggiani and Peter Nijkamp (ed). Cheltenham, UK: Edward Elgar.

Dellaert, B.G.C., Arentze, T.A. & Timmermans, H.J.P. (2008). "Shopping context and consumers' mental representation of complex shopping trip decision problems" *Journal of Retailing, 84*(2, 2008) 219–232.

Desyllas, J. (1999). "When downtown moves", Proceedings, Space Syntax Second International Symposium.

Drezner, T., Drezner, Z. & Shiode, S. (2002). "A Threshold-satisfying Competitive Location Model", *Journal of Regional Science, 42*(2), 287-299.

Enström, R. & Netzell, O. (2008). "Can Space Syntax Help Us in Understanding the Intraurban Office Rent Pattern? Accessibility and Rents in Downtown Stockholm", *Journal of Real Estate Finance and Economics*, *36*(3), 289-305.

Hanson, J. (1998). *Decoding Homes and Houses*, Cambridge: Cambridge University Press.

Hillier, B. (1988). "Against enclosure" in *Rehumanising Housing*, N. Teymur, T. Markus, T. Wooley (ed). London: Butterworths.

Hillier, B. (1996). *Space is the Machine*, Cambridge: Cambridge University Press.

Hillier, B. & Hanson, J. (1984). *The Social Logic of Space*, Cambridge: Cambridge University Press.

Hillier, B., Burdett, R., Peponis, J. & Penn, A. (1987). "Creating life: Or, does architecture determine anything?", *Architecture and Behaviour, 3*(3), 233-250.

Hillier, B., Hanson, J., Peponis, J., Hudson, J. & Burdett, R. (1983). "Space syntax: a new urban perspective", *Architects Journal, 178*(48), 48-63.

Hillier, B., Penn, A., Hanson, J., Grajewski, T. & Xu, J. (1993). "Natural Movement: or, Configuration and Attraction in Urban Pedestrian Movement", *Environment and Planning B, 20*(1), 29-66.

Hossain, N. (1999). "A Syntactic Approach to the Analysis of Spatial Patterns in Spontaneous Development in Dhaka", Proceedings, Space Syntax Second International Symposium.

Kim, H. & Sohn, D.W. (2002). "An analysis of the relationship between land use density of office buildings and urban street configuration", *Cities, 19*(6), 409–418.

LeSage, J.P. & Pace, R.K. (2004). "Introduction to Spatial and Spatiotemporal Econometrics" in *Advances in Econometrics: Volume 18: Spatial and Spatiotemporal Econometrics*, James P. LeSage and R. Kelley Pace (ed). Oxford, UK: Elsevier Ltd.

Marcus, L. (2000). "Architectural Knowledge and Urban Form-The Functional Performance of Architectural Urbanity", Doctoral thesis, Royal Institute of Technology, Stockholm.

Netzell, O. (2003). "The influence of integration values on office rents", MSc Thesis, Royal Institute of Technology, Sweden.

Penn, A. (2003). "Space Syntax and Spatial Cognition: Or Why the Axial Line?", *Environment and Behavior, 35*(1), 30-65.

Peponis, J., Hadjinikolaou, E., Livieratos, C. & Fatouros, D.A. (1989). "The Spatial Core of Urban Culture", *Ekistics, 56*(334/335), 43-55.

Popkowski Leszczyc, P.T.L., Sinha, A. & Sahgal, A. (2004). "The effect of multi-purpose shopping on pricing and location strategy for grocery stores", *Journal of Retailing, 80*(2) 85–99.

Söderberg, B. & Janssen, C. (2001). “Estimating Distance Gradients for apartment Properties”, *Urban Studies*, *38*(1), 61-79.

Teklenburg, J.A.F., Timmermans, H.J.P. & van Wagenberg, A.F. (1993). “Space syntax: Standardised integration measures and some simulations”, *Environment and Planning B: Planning and Design, 20*(3), 347–357.

Vandell, K.D. & Carter, C.C. (1993). “Retail Store Location and Market Analysis: A Review of the Research”, *Journal of Real Estate Literature, 1*(1), 13-45.

Wooldridge, J.M. (2003). “Cluster-Sample Methods in Applied Econometrics”, *The American Economic Review, 93*(2), 133-138.