Spatial and functional differentiation:
A symbiotic and systematic relationship

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Abstract:
Urban areas vary widely, not only in terms of social differentiation, i.e. classes and groups, and functional differentiation, i.e. types of activity and land-use, but also in terms of morphological character, i.e. the physical and spatial characteristics that give an area its primary identity. Is there then a relationship between spatial and functional patterns? Recent authors, such as Krafta (1994) and Siksna (1997), have outlined aspects of a possible systematic relationship, while Hillier (1996) has suggested a general linkage between one and the other through the ability of the spatial structure to influence movement patterns, and through this to influence the pattern of land-use specialisation.

This paper is a report of a study of the spatial and functional differentiation of urban areas in Bangkok. Thirty areas were studied in total. Hillier's theories of 'natural movement', 'movement economy', 'centrality as a process' and 'the city as object' were applied (Hillier, 1984, 1996, 2000, 2001). Space syntax techniques coupled with geometric measurements were used for the study of spatial pattern, while a land-use survey was carried out to reveal the functional pattern. Movement patterns were also investigated.

The findings show that: there is a systematic relationship between area structure and dominant land-use type; in spite of the differences in the spatial structure of the more recent areas and the evolving changes in the structure of the city within which the areas are embedded, the pattern of the spatial and functional differences has not changed; and, it is the actual lay-out and micro details of local area structure that influence the functional development of an area. Thus, this relationship also affects the land value of areas.

The results are then used to address the generative process theorised by Hillier. Through the feedback mechanism between spatial structure, movement and land use, the characteristics of the urban grid are determined by the degree to which movement economy is promoted or controlled, in relation to micro-economy or privacy and cultural constraints. A functional area which benefits greatly from movement develops in an area with a highly-integrated grid structure capable of generating strong movement economy, particularly at the local level. A functional area which benefits less from movement is developed elsewhere, although all grid structure are capable of generating a certain degree of local movement economy.

Keywords
Areal differentiation, area structure, micro-distribution of retail function, land value, Bangkok

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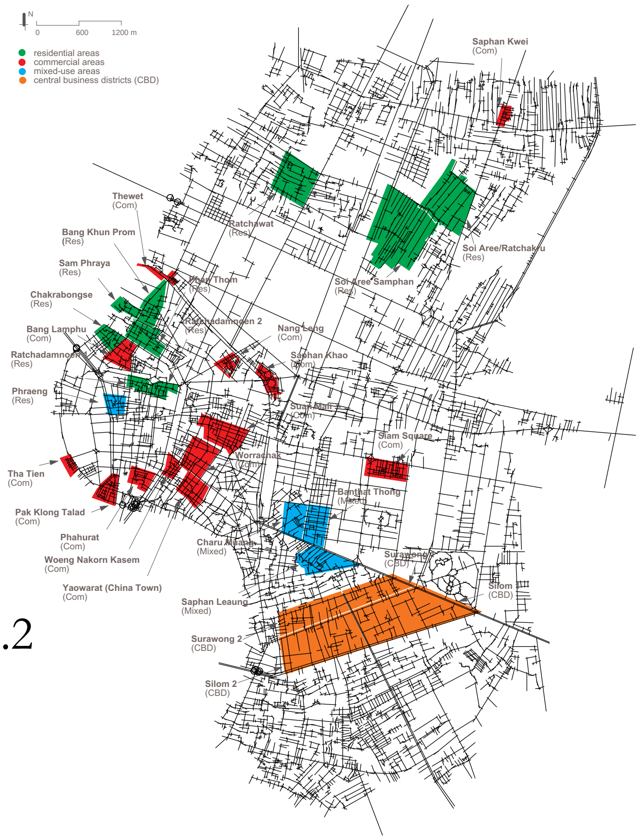

Figure 1: Location of the 30 selected areas, in the historic and extended areas of Bangkok;
showing the areas categorised by their dominant land uses and superimposed on the extended map

1. Introduction

The study and its results reported in this paper aim to establish whether there is a systematic relationship between spatial differences and the functional differentiation of areas, as suggested by the studies of Krafta (1994) and Siksna (1997). If there is, how does the relationship between spatial structure and functional differentiation develop? And how is land value related to this process? Details of the spatial configuration of local areas in different parts of Bangkok were examined, both as an independent system and as a system embedded within the city structure, with a focus on spatial differentiation and functional specialisation across areas and within areas. In total, 30 areas of Bangkok were studied for the differentiation across areas (Figure 1). Of these 30 areas, eight were selected for the intensive study of the differentiation within area, involving movement patterns and focusing on the micro-distribution of the retail function.

2. Theoretical background

Four theories of Hillier, the theory of 'natural movement', the theory of 'movement economy', the theory of 'centrality as a process' and the theory of 'the city as object' (Hillier, 1984, 1996, 2000, 2001), provided the theoretical background of the study. The theory of 'natural movement' suggests that movement pattern is influenced by the spatial configuration of the urban grid, made up of a group of lines, i.e., axial lines. It also argues that while we may find movement and attractors (land-use or functional types which benefit greatly from movement and by themselves are capable of generating movement, such as retail shops) highly related to each other, we cannot assume that movement can be explained by attractors until we can be sure that the configurational properties of the grid have not influenced both the presence of movement and the presence of attractors (Hillier, 1984). The key here is that while the grid configuration can directly influence both the patterns of movement and attractor distribution, movement and attractors cannot directly influence the grid parameters.

The theory of 'movement economy' explains the mechanism which generates the common strong association between movement and attractors. According to this theory, it is the grid structure that initially influences the pattern of movement, and they then affect the distribution of attractors, which in turn attracts more movement into the grid, creating the multiplier effect on movement (Hillier, 1996).

The theory of 'centrality as a process' concerns the mechanism which generates the spatial characteristics of a functional land-use type of areas which benefits highly from movement. The key to this process is the minimisation of mean trip length in order to generate movement economy within the local grid (Hillier, 2000). Mean trip length is minimised through 'metric integration', that is, the minimisation of both the configurational distance (the topological distance to go from A to B) and the metric distance (the specific distance to go from A to B).

The theory of 'the city as object' suggests that there is a generative process, which has a dual characteristic working through socio-cultural and micro-economic forces, and which gives rise to the variation and invariants of area structure across cities (Hillier, 2001). The socio-cultural process generates the variation in urban grids across cities, mostly seen in residential areas and influenced by variety in tastes, norms, standards, etc., through the degree to which movement economy is controlled. The micro-economic process generates the invariants, i.e., the deformed-wheel shape of the global city structure and the compact and integrated local grid structure of a functional area which benefits highly from movement in order to promote movement economy. Accordingly, the study hypothesised that spatial structure is the primary factor influencing functional development across and within areas, through its ability to influence the pattern of movement, and so facilitate different land-use specialisation in different areas, with different spatial structures to accommodate these functional differences.

3. Areal differentiation

The 30 areas studied (Figure 1) include four different land-use types: residential, commercial, mixed-use and central business district (CBD). They were selected from two different parts of Bangkok, the historic area and the immediate areas surrounding the historic area (the extended area), in an attempt to examine whether changes in the city structure as the city has expanded might affect the spatial differentiation across functional types. Of these 30 areas, 16 of them are located in the historic area, and 14 are located in the extended area. Nine areas are residential areas. Six of these are located in the historic area (Bang Khun Prom, Chakrabongse, Ratchadamnoen 1, Ratchadamnoen 2, Phan Thom and Sam Phraya) and three in the extended area (Ratchawat, Soi Aree Samphan and Soi Aree/Ratchakru). 13 areas are commercial areas. Nine of these are located in the historic area (Nang Leng, Bang Lamphu, Suan Mali, Tha Tien, Pak Klong Talad, Phahurat, Woeng Nakorn Kasem, Worrachak and Yaowarat), and four are located in the extended area (Thewet, Saphan Kwei, Saphan Khao and Siam Square). Four areas are mixed-use areas. One is located in the historic area (Phraeng), and three in the extended area (Banthat Thong, Charu Muang and Saphan Leaung). The last four areas are CBD areas. All of them (Silom 1, Silom 2, Surawong 1 and Surawong 2) are located in the extended area.

The grids of the areas were measured for the ratio of islands over lines (I/L ratio), geometrical properties (average block size, average line length within area and average full line length), and syntactic properties (connectivity, radius-n integration, radius-3 integration, radius-radius integration, intelligibility and synergy). For the syntactic properties, each grid was measured as an independent system and as a system embedded within the city structure, either the structure of the historic area or the structure of the historic and extended areas. The difference in syntactic values between the embedded and non-embedded system were also included as spatial variables. Moreover, the surrounding roads of the grids were also studied, but in relation to the embedded system only. The surrounding roads were examined at two levels: lines directly connecting to the grid and lines connecting at two steps out of the grid.

Table 1: A comparison of the mean spatial values of the grids of the four dominant land-use areas;
showing the mean values of the historic residential and commercial areas analysed with the historic map and the mean values of the extended residential, commercial, mixed-use and CBD areas analysed with the extended map
(notes: emb = grid analysed with the embedding; ind = grid analysed without the embedding; * = statistically significant; conn = connectivity; integ-n/3/6/7 = radius-n/3/6/7 integration; intell = intelligibility; diff = difference between embedded and non-embedded syntactic value; resid = residential areas; comm = commercial areas)

	Analysed with the historic map			Analysed with the extended map						
	Historic local areas			Extended local areas						
	Resid areas	Comm areas	Difference comm/resid	Resid areas	Comm areas	Diff comm/resid	Mixed-use	Diff mixed/comm	CBD	Diff CBD/comm
number of lines	26.00	21.56	0.829	42.67	23.00	0.539	31.00	1.348	31.00	1.348
number of islands	*8.17	16.22	1.986	9.00	12.50	1.389	15.00	1.200	13.75	1.100
I/L	*0.307	*0.767	2.498	*0.210	0.513	2.443	0.537	1.047	0.466	0.908
full line length-m.	*197.27	305.81	1.550	360.70	335.84	0.931	439.50	1.309	*574.17	1.710
line length within area	*95.36	141.99	1.489	183.45	*107.68	0.587	156.12	1.450	246.60	2.290
block mesh-m.	93.38	74.15	0.794	*201.64	*64.82	0.321	132.89	2.050	187.36	2.890
connectivity (emb)	*4.148	6.133	1.479	4.327	5.577	1.289	6.057	1.086	7.055	1.265
integ-n (emb)	1.290	1.460	1.132	*1.173	1.41	1.202	1.460	1.035	*1.473	1.045
integ-3 (emb)	*2.175	2.878	1.323	*1.990	2.697	1.355	2.633	0.976	2.988	1.108
integ-6/7 (emb)	*1.582	1.858	1.174	1.570	1.905	1.213	1.947	1.022	*2.053	1.078
intelligibility (emb)	0.538	0.537	0.998	0.435	0.571	1.313	0.549	0.961	0.543	0.951
synergy (emb)	0.745	0.725	0.973	*0.630	0.824	1.308	0.816	0.990	0.848	1.029
connectivity (ind)	*2.772	*3.703	1.336	*2.606	3.172	1.217	3.144	0.991	3.04	0.958
integ-n (ind)	*1.084	1.603	1.479	1.085	1.428	1.316	1.343	0.940	1.444	1.011
integ-3 (ind)	*1.654	*2.135	1.291	*1.571	1.950	1.241	1.884	0.966	1.945	0.997
intelligibility (ind)	0.622	0.760	1.222	0.583	0.665	1.141	0.615	0.925	0.656	0.986
synergy(ind)	0.696	0.801	1.151	0.702	0.736	1.048	0.718	0.976	0.810	1.101
conn diff (emb-ind)	*1.377	2.431	1.765	1.721	2.406	1.398	2.913	1.211	4.015	1.669
integ-n diff (emb-ind)	*0.206	-0.143	-0.694	0.088	-0.018	-0.205	0.117	-6.500	0.029	-1.611
integ-3 diff (emb-ind)	0.521	0.743	1.426	0.419	0.747	1.783	0.749	1.003	1.042	1.395
intell diff (ind-emb)	*0.084	0.223	2.655	0.148	0.094	0.635	0.066	0.702	0.112	1.191
synergy diff (ind-emb)	-0.049	0.075	-1.531	0.072	-0.087	-1.208	-0.097	1.115	-0.038	0.437

The average spatial values of the area grids were then compared in relation to the land-use types and the axial analysed maps, i.e., the historic map (the axial analysed map of the historic area) and the extended map (the axial analysed map of the historic and extended areas combined). This included: a comparison of the historic residential and commercial areas analysed with the historic map; a comparison of the extended residential, commercial, mixed-use and CBD areas with the extended map; and a comparison of all the historic and extended land-use areas analysed with the extended map. The results of the three comparisons show similar patterns, and they are more pronounced in the first and second comparisons (Table 1) than the third.

The results show that there is a systematic relationship between spatial differences and the functional differentiation of areas. Of the four land-use types, the relationship between spatial differences and functional differentiation is more pronounced, as would be expected, between the residential and commercial land-use types than between the commercial and mixed-use and CBD land-use types. Despite the city's expansion, and the accompanying changes in spatial structure, the relationship between spatial differences and the residential and commercial land-use types remains intact; the residential areas consistently have a more broken and segregated grid structure and are made up of larger blocks and fewer islands, whereas the commercial areas consistently have a more orthogonal and integrated grid structure and are made up of smaller blocks and more islands (Table 1). The difference between the residential and the commercial areas can also be seen from the ways in which they develop. The development of the residential areas is relatively independent of the structure of their surroundings, as seen from the marginal difference between the embedded and non-embedded syntactic values, which indicates that the local grid structure of the residential areas remains more or less the same with or without the city structure. This is in marked contrast to the development of the commercial areas, which are highly dependent on their surrounding; the integration values of the commercial grids increase substantially when the grids are embedded within the city structure. This highlights the fact that the residential areas only require global access, while the commercial areas need an integrated location well related to an integrated internal structure in order to capitalise on the natural movement generated by the configuration of that location.

The spatial differences between the commercial, mixed-use and CBD land-use types are more subtle. The grid of the mixed-use areas is usually a geometrically enlarged version of the commercial grids. The mixed-use grid is made up of more long lines and has a larger-scale block structure than the commercial grid (Table 1). The grid of the CBD areas is both a geometrically and configurationally enlarged version of the commercial grid; it is generally made up of more long lines and with a larger-scale block structure and a more integrated grid structure than the commercial grids (Table 1). The development of mixed-use areas could not be established, due to the fact that most of the mixed-use areas studied are located close to the CBD areas, and therefore it seems that their development is influenced by the global integration which influences the development of the CBD areas. The development of the CBD areas is most dependent on the city's structure. They have developed close to the centre of the deformed-wheel structure of the city. As the most economically important land use of the city, here they can take advantage of globally integrated locations.

4. Detailed study of eight areas with an emphasis on the micro-distribution of the retail function

The detailed study of the inter-relation between spatial structure, movement, and retail land use of the eight areas (Chakrabongse, Phan Thom, Bang Lamphu, Yaowarat, Nang Leng, Ratchakru, Banthat Thong and Surawong 1) was carried out by two analyses: an analysis of the eight areas, in which all areas were analysed together; and an area-by-area analysis, in which areas were individually analysed. The areas were analysed on two levels: first at the level of the area, in which the unit of analysis is the areas themselves; and second at the line level, in which all the lines which make up the areas are grouped into a single data table and therefore the line is the unit of analysis. This means that the results for the area level, in which we are most interested but for which there are too few cases for a full multivariate analysis, can be checked against a full multivariate analysis at the line level where there are 212 cases.

Spatially, the grids of the eight areas were measured for line length and line configuration (through axial analysis). There are nine spatial variables at the line level: full line length; line length within area; embedded and non-embedded connectivity; embedded and non-embedded radius-n integration; embedded and non-embedded radius-3 integration; and embedded radius-7 integration. At the area level, there are 20 spatial variables: the nine spatial variables of the line level analysis; embedded and non-embedded intelligibility; embedded and non-embedded synergy; five syntactic differences between the values of the embedded and non-embedded grid; block size; and I/L ratio. The extended map was chosen as the embedding system, because it is the system in which all eight areas are embedded.

For movement density, observations were made of a series of pedestrian and vehicular types (car and small van, taxi, tuk-tuk or motor-tricycle taxi, motorcycle, bus and others), using the gate method. In total, 268 gates were observed, and the total observed time of all the gates combined was over 214 hours. For every gate, movement was observed for three minutes per hour, every hour from 10 am to 6 pm, on a weekday and a Saturday. The total number of each movement type, divided by groups (pedestrian and vehicular) and sub-groups (vehicle type), for each gate was averaged and calculated to obtain the density per hour of each gate. If a line has more than one gate, all the movement densities per hour of all the observation gates of that line were averaged, to obtain the movement density per hour of the line.

For retail distribution, a survey of the eight areas was carried out to identify the exact locations of the retail function and to count four retail variables - retail premises, retail entrance, retail unit and stall - on every grid line of each area. A retail premises is a place where retail trade is conducted, and it will be referred to as a retail shop in this paper. A retail entrance is an entrance from a street into a retail shop, and a retail shop can have more than one entrance. A retail unit is a five-metre-wide unit of a building in which a retail shop in Bangkok is normally housed. Again, a retail shop can be housed within more than one retail unit, which in turn can have more than one entrance. A stall is a retail counter, which must be moveable. Retail density was chosen in order to investigate retail distribution. The retail density of a line was calculated by dividing the sum total of a retail variable of a grid line with line length within area of that line. Moreover, density variations, for example, the density of retail shops and stalls combined, the density of retail entrances and stalls combined and the density of retail units and stalls combined, calculated by the same method, were also added as retail variables in order to ensure the rigour of the statistical analysis.

The analysis of the eight areas combined was carried out at both the area and line levels and through statistical analysis, while the analysis of individual areas was carried out at the line level only, but through both graphical and statistical analyses. However, there are three problems in the statistical analysis. The first is a common problem found in many statistical analyses dealing with a large number of values and various variables in each of the dependent variable groups: a skewed distribution curve of values towards low values. A normalisation was applied through arithmetic functions where there was a skewed distribution curve towards low values, and these adjusted values were used in the statistical analysis. For the spatial variables, log function was applied to full line length, line length within area and embedded connectivity. The fourth root was applied to each of the movement variables, while square root was applied to the retail variables.

A series of preliminary multivariate analyses was carried out to identify the influential movement and retail variables. It was found that the fourth root of pedestrian movement density per hour (PED) and the fourth root of vehicular movement density per hour (VEH) were the powerful movement variables. The most powerful retail variable was the square root of retail entrance density (RED). These powerful variables were then used as the dependent variables in the statistical analysis. For each area the values of these powerful variables as well as the integration values were used to draw a series of range maps to form the basis of the graphical analysis at the line level of individual areas.

The second problem is that the spatial variables are strongly correlated with each other.[1] A series of experimental multivariate analyses was carried out using nine spatial variables and PED (which is the key theoretical factor driving the whole
11.8 movement economy and centrality theory) in all eight areas taken together to try to reduce the number of variables to those where this relation was most powerful. All the spatial variables were regressed individually against PED, giving significant positive correlations in all cases, with log embedded connectivity, embedded radius-3 integration and embedded radius-7 integration being the strongest, and in general the syntactic variables being stronger than the geometric ones. Variables such as log embedded connectivity and embedded radius-3 integration are strongly correlated (r-value .943), as are embedded radius-7 integration and embedded radius-n integration (r-value .966). When a stepwise regression was carried out, six variables were found to be significant - led by log embedded connectivity and embedded radius-7 integration. The variables most closely resembling each of these, embedded radius-3 integration and length in the case of log embedded connectivity, and embedded radius-n integration in the case of embedded radius-7 integration, turned weakly negative, clearly as a result of the presence of the more dominant variable. Multiple regression of the two dominant variables gave a combined r-squared value of .406, in contrast to .496 for all nine. Because - confirming the factor analysis in the footnote - one of these was a local (log embedded connectivity) and the other a global variable (embedded radius-7 integration), it was then decided to use these two as the lead spatial variables in the area analysis. This is not to rule out the possibility that in particular cases the other local and global variables will be more important.

The third problem is more substantive and not capable of a purely technical solution. According to Hillier's theories of 'natural movement', 'movement economy' and 'centrality as a process', spatial structure, movement pattern and retail distribution are inter-related and there are two key issues in their interrelationships. One is that spatial structure first influences movement and then influences land-use pattern, which in turn creates a multiplier effect on movement, and, where the process becomes intensive, feedback effects the spatial structure of the area grid. The other is that while movement can be influenced by spatial values, of the line or the area, it cannot directly influence those values. Similarly, retail distribution can be affected by spatial values through their effect on movement, but retail distribution cannot directly affect those spatial values. It is impossible to disentangle these complex interrelations over time using a synchronous analysis of all the variables together. We therefore are not seeking to compare spatial factors with movement factors in their effect on the pattern of retail distribution, since the spatial pattern will already have influenced movement and produced the multiplier effect (so that most movement may in practice be due to the presence of the shops) but to isolate which spatial factors, if any, influence movement pattern, and then to explore the relation between spatial factors and the pattern of retail distribution. What we are interested in is the role of the spatial structure in the micro-distribution of movement and retail function in the areas, and the spatial, movement and retail impact on land value. We then seek to identify some general patterns by asking a series of questions. How do syntactic and geometric variables affect the different types of movement (PED and VEH) at the level of both the difference between lines within the area and differences in average movement rates between areas? How do syntactic and geometric variables affect the pattern of retail distribution (RED)? How do different types of movement (PED and VEH) relate to the pattern of retail distribution (RED)? And, how do all these factors relate to land value, which will be discussed in the next section? The key issue, then, may be the *'type'* of spatial variable that movement, retail and land value variables are most associated with, i.e., whether it is local, global, or mid-range, syntactic or geometric, and so on.

When the eight areas are analysed together at both the area and line levels, the results show that: the higher the syntactic value is the higher the value of PED and VEH will be; and, the more local the syntactic variable is the stronger the factor it is for PED and VEH (Tables 2 and 3). However, at the micro-scale of the line, there is evidence of global factors having more influence for both PED and VEH, and in both cases, the global factor is related to the way in which the local area grid is embedded in the larger system. The geometric variables are less influential for PED and VEH than the syntactic variables, and affect PED and VEH differently. Both at the area and line levels, there is no significant effect of average line length on PED, while in the case of VEH the longer the line is the higher the value of VEH will be. In terms of blocks, which can only be measured at the area level, PED decreases when blocks get larger, while VEH increases.

The effects of syntactic and geometric variables on RED, for both the area and line levels, are similar to their effects on PED. The syntactic variables are stronger for RED than the geometric variables. The higher the syntactic value is, the higher the value of RED will be at both the area and line levels. The more local the syntactic variable is, the stronger the factor it is for RED. Line length has a relatively weak impact on RED. Finally, RED decreases where blocks are getting larger. Due to these similarities, it is not surprising that, for both the area and line levels, PED and RED are strongly related to each other: the more pedestrian movement there is, the higher the retail density will be. As for VEH, while VEH is strongly related to RED at the area level, this is not the case at the line level.

Table 2: A correlation metric of spatial, movement, retail and land value variables of the eight areas combined
(notes: emb = grid analysed with the embedding; ind = grid analysed without the embedding; conn = connectivity; integ-n/3/7 = radius-n/3/7 integration; intell = intelligibility; diff = difference between embedded and non-embedded syntactic value; LVA96 = log average land value in 1996; LVR = log average rise in land value 1996/88)

	RED	I / L	ln(x)conn (emb)	integ-3 (emb)	integ-7 (emb)	integ-n (emb)	intell (emb)	synergy (emb)	conn (ind)	integ-3 (ind)	integ-n (ind)	intell (ind)	synergy (ind)
RED	1												
I / L	0.69	1											
ln(x)conn(emb)	0.68	0.783	1										
integ-3(emb)	0.829	0.855	0.928	1									
integ-7(emb)	0.648	0.778	0.96	0.955	1								
integ-n(emb)	0.573	0.833	0.921	0.93	0.977	1							
intell(emb)	-0.02	0.472	0.599	0.469	0.626	0.68	1						
synergy(emb)	0.045	0.417	0.569	0.433	0.593	0.595	0.823	1					
conn(ind)	0.809	0.969	0.728	0.852	0.712	0.753	0.325	0.269	1				
integ-3(ind)	0.829	0.961	0.787	0.915	0.796	0.824	0.331	0.246	0.979	1			
integ-n(ind)	0.806	0.836	0.782	0.885	0.789	0.816	0.213	0.135	0.872	0.917	1		
intell(ind)	0.243	0.41	0.341	0.377	0.401	0.473	0.036	0.28	0.369	0.374	0.586	1	
synergy(ind)	0.235	0.557	0.315	0.434	0.45	0.538	0.109	0.33	0.471	0.496	0.538	0.855	1
connDiff(emb-ind)	0.425	0.496	0.918	0.749	0.875	0.805	0.671	0.65	0.403	0.485	0.527	0.221	0.125
integ-3Diff(emb-ind)	0.641	0.536	0.886	0.876	0.93	0.847	0.527	0.558	0.508	0.607	0.648	0.295	0.261
integ-nDiff(emb-ind)	-0.793	-0.649	-0.503	-0.652	-0.473	-0.497	0.176	0.23	-0.761	-0.776	-0.907	-0.536	-0.415
intellDiff(ind-emb)	0.175	-0.099	-0.242	-0.118	-0.224	-0.219	-0.755	-0.458	-0.012	-0.012	0.219	0.628	0.476
synergyDiff(ind-emb)	0.129	0.006	-0.318	-0.1	-0.242	-0.18	-0.714	-0.722	0.086	0.127	0.263	0.357	0.414
ln(x) avFull line length	0.451	0.618	0.918	0.739	0.82	0.795	0.634	0.475	0.542	0.6	0.646	0.211	0.083
ln(x) avLengthwithinarea	0.414	0.555	0.727	0.567	0.573	0.565	0.446	0.134	0.528	0.561	0.564	-0.06	-0.169
ln(x) block mesh	-0.337	-0.571	-0.179	-0.429	-0.353	-0.414	-0.197	-0.363	-0.548	-0.529	-0.326	-0.342	-0.704
VEH	0.777	0.364	0.678	0.638	0.549	0.437	0.062	0.078	0.478	0.497	0.623	0.149	-0.15
MCY	0.766	0.66	0.835	0.818	0.744	0.709	0.371	0.165	0.72	0.754	0.806	0.139	-0.023
PED	0.807	0.212	0.429	0.584	0.458	0.31	-0.194	0.001	0.351	0.41	0.463	0.124	0.057
LVA96	0.728	0.586	0.86	0.893	0.901	0.815	0.497	0.578	0.587	0.655	0.649	0.275	0.263
LVR96/88	-0.001	0.396	0.231	0.374	0.445	0.58	0.363	0.267	0.303	0.373	0.451	0.627	0.769

	connDiff (emb-ind)	integ-3 Diff (emb-ind)	integ-n Diff (emb-ind)	intell Diff (ind-emb)	synergy Diff (ind-emb)	ln(x)Full line length	ln(x) Length within area	ln(x) block mesh	VEH	MCY	PED	LVA96	LVR96/88
RED													
I / L													
ln(x)conn(emb)													
integ-3(emb)													
integ-7(emb)													
integ-n(emb)													
intell(emb)													
synergy(emb)													
conn(ind)													
integ-3(ind)													
integ-n(ind)													
intell(ind)													
synergy(ind)													
connDiff(emb-ind)	1												
integ-3Diff(emb-ind)	0.893	1											
integ-nDiff(emb-ind)	-0.205	-0.356	1										
intellDiff(ind-emb)	-0.378	-0.217	-0.489	1									
synergyDiff(ind-emb)	-0.534	-0.347	-0.527	0.79	1								
ln(x) avFull line length	0.919	0.738	-0.391	-0.355	-0.397	1							
ln(x) avLengthwithinarea	0.671	0.445	-0.435	-0.387	-0.254	0.892	1						
ln(x) block mesh	0.064	-0.212	0.188	-0.071	-0.165	0.168	0.331	1					
VEH	0.623	0.663	-0.618	0.05	-0.185	0.651	0.602	0.247	1				
MCY	0.708	-0.693	0.71	-0.198	-0.176	0.835	0.836	0.081	0.864	1			
PED	0.349	0.66	-0.469	0.233	0.041	0.176	0.027	-0.203	0.716	0.973	1		
LVA96	0.82	0.975	-0.381	-0.207	-0.365	0.657	0.374	-0.331	0.683	0.801	0.733	1	
LVR96/88	0.139	0.29	-0.255	0.128	0.306	0.107	-0.109	-0.565	-0.272	-0.127	-0.099	0.234	1

	RED	ln(x) conn (emb)	integ-3 (emb)	integ-7 (emb)	integ-n (emb)	conn (ind)	integ-3 (ind)	integ-n (ind)
RED	1							
ln(x) conn-emb	0.576	1						
integ-3(emb)	0.566	0.943	1					
integ-7(emb)	0.541	0.721	0.854	1				
integ-n(emb)	0.513	0.689	0.81	0.966	1			
conn(ind)	0.476	0.746	0.679	0.517	0.491	1		
integ-3(ind)	0.507	0.779	0.757	0.617	0.581	0.953	1	
integ-n(ind)	0.551	0.688	0.718	0.695	0.686	0.818	0.855	1
ln(x)full line length	0.495	0.882	0.887	0.744	0.71	0.634	0.685	0.645
ln(x)length within area	0.441	0.708	0.718	0.635	0.588	0.705	0.746	0.674
VEH	0.524	0.765	0.741	0.639	0.608	0.587	0.633	0.602
MCY	0.545	0.755	0.67	0.739	0.662	0.609	0.667	0.64
PED	0.741	0.601	0.588	0.583	0.522	0.465	0.533	0.538
LVA96	0.561	0.382	0.451	0.646	0.666	0.295	0.354	0.467
LVR96/88	-0.187	-0.142	-0.107	0.05	0.17	-0.097	-0.061	0.053

	ln(x) full line length	ln(x)length within area	VEH	MCY	PED	LVA96	LVR96/88
RED							
ln(x) conn-emb							
integ-3(emb)							
integ-7(emb)							
integ-n(emb)							
conn(ind)							
integ-3(ind)							
integ-n(ind)							
ln(x)full line length	1						
ln(x)length within area	0.875	1					
VEH	0.764	0.676	1				
MCY	0.743	0.684	0.965	1			
PED	0.498	0.466	0.629	0.963	1		
LVA96	0.329	0.264	0.409	0.669	0.696	1	
LVR96/88	-0.216	-0.2	-0.232	-0.105	-0.07	0.151	1

Table 3: A correlation metric of spatial, movement, retail and land value variables of all the lines making up the eight areas
(notes: emb = grid analysed with the embedding; ind = grid analysed without the embedding; conn = connectivity; integ-n/3/7 = radius-n/3/7 integration; LVA96 = log average land value in 1996; LVR = log average rise in land value 1996/88)

When the areas are analysed individually, the spatial effects on PED, VEH and RED are similar to those found from the analysis of the eight areas combined, although the influential spatial factors among individual areas are more varied than those of the eight areas combined (Tables 4 and 5). Despite the idiosyncrasies in the pattern of micro-distribution of the retail function in individual areas, spatial factors can account in some way for most of the differences in the patterns of individual areas. The distribution is influenced by the local grid structure. The retail function is most likely to develop at locations, whether the intersections, line segments or the lines themselves, that minimise mean trip length within the grid, configurationally and geometrically, and that therefore have potential for movement, benefiting the retail function. Most often, but not always, these locations include the major grid lines.

	Area level	**Line level**
A. Important variables for PED, VEH and RED		
1. The most powerful spatial variables against PED	**integ-3 diff(emb-ind)**	**logConn(emb)**
2. The most powerful spatial variables against VEH	**logConn(emb)**	**logConn(emb)**
3. The most powerful spatial variables against RED	**integ-3(ind)**	**logConn(emb)**
4. Critical movement variable for RED	**PED**	**PED**
5. The most powerful variables against RED	**PED**	**PED**
	conn(ind)	integ-n(ind)
B. Important variables for LVA96 and LVR96/88		
1. Against LVA96		
a. The most powerful spatial variables against LVA	**integ-7(emb)**	**integ-n(emb)**
	integ-n(emb)	log full line length
b. Critical movement variable for LVA	**PED**	**PED**
c. The most powerful variables against LVA	**integ-7(emb)**	**integ-n(emb)**
	PED	
2. Against LVR96/88		
a. The most powerful spatial variables against LVR	**none**	**integ-n(emb)``**
	integ-n(emb) (closet)	integ-7(emb)``
b. Critical movement variable for LVR	**VEH^**	**VEH^ ``**
c. The most powerful variables against LVR	**none**	**integ-n(emb)``**
	integ-n(emb) (closet)	integ-7(emb)``

Table 4: A summary of the factors most influencing movement, retail distribution, and land value and rise in land value of the eight areas combined; showing the most powerful variables in descending order identified in the stepwise regression of spatial variables against PED, VEH, RED and land value variables
(notes: emb = grid analysed with the embedding; ind = grid analysed without the embedding; conn = connectivity; integ-n/3/7 = radius-n/3/7 integration; diff = difference between embedded and non-embedded syntactic value; LVA96 = log average land value in 1996; LVR = log average rise in land value 1996/88; ^ = negative correlation; `` = insignificant correlation)

	Chakrabongse	Phan Thom	Bang Lamphu	Yaowarat
A. Important variables for PED, VEH and RED				
1. The most powerful spatial variables against PED	**logConn(emb)** logfulllinelength	**integ-7(emb)** integ-n(ind)	**integ-3(ind)**	**integ-3(ind)**
2. The most powerful spatial variables against VEH	**logConn(emb)**	**integ-3(emb)**	**integ-3(ind)** conn(ind)	**integ-3(ind)**
3. The most powerful spatial variables against RED	**integ-3(emb)** integ-7(emb)	**integ-3(emb)**	**logConn(emb)**	**logConn(emb)**
4. Critical movement variable for RED	**VEH**	**VEH**	**PED**	**PED**
5. The most powerful variables against RED	**integ-3(emb)**	**VEH**	**logConn(emb)** PED	**PED**
B. Important variables for LVA96 and LVR96/88				
1. Against LVA96				
a. The most powerful spatial variables against LVA	**integ-3(emb)**	**integ-3(emb)** integ-7(emb)	**integ-3(ind)**	**nothing**
b. Critical movement variable for LVA	**PED**	**VEH**	**PED**	**VEH**
c. The most powerful variables against LVA	**integ-3(emb)**	**VEH** integ-n(ind)	**PED**	**VEH**
2. Against LVR96/88				
a. The most powerful spatial variables against LVR	**logConn(emb)^** integ-3(ind)^	**logConn(emb)^** loglengthwithinarea^	**nothing**	**nothing**
b. Critical movement variable for LVR	**VEH^**	**VEH^**	**PED^**	**VEH^**
c. The most powerful variables against LVR	**logConn(emb)^** integ-3(ind)^	**logConn(emb)^** loglengthwithinarea^	**RED^**	**VEH^**

	Nang Leng	Ratchakru	Banthat Thong	Surawong 1
A. Important variables for PED, VEH and RED				
1. The most powerful spatial variables against PED	**logConn(emb)**	**logConn(emb)**	**integ-3(emb)**	**conn(ind)**
2. The most powerful spatial variables against VEH	**logfulllinelength** loglengthwithinarea	**logConn(emb)**	**integ-3(emb)** logfulllinelength	**logConn(emb)**
3. The most powerful spatial variables against RED	**logfulllinelength**	**logConn(emb)**	**logConn(emb)**	**nothing**
4. Critical movement variable for RED	**PED**	**PED**	**PED**	**PED**
5. The most powerful variables against RED	**logfulllinelength** loglengthwithinareas	**PED**	**logConn(emb)**	**PED**
B. Important variables for LVA96 and LVR96/88				
1. Against LVA96				
a. The most powerful spatial variables against LVA	**logfulllinelength**	**integ-3(emb)** integ-3(ind) logfulllinelength	**logfulllinelength** loglengthwithinarea	**conn(ind)** logfulllinelength^
b. Critical movement variable for LVA	**VEH**	**VEH**	**VEH**	**PED**
c. The most powerful variables against LVA	**VEH** integ-n(emb)	**integ-3(emb)** integ-3(ind) logfulllinelength	**VEH** conn(ind)	**PED**
2. Against LVR96/88				
a. The most powerful spatial variables against LVR	**logfulllinelength^**	**nothing**	**nothing**	**nothing**
b. Critical movement variable for LVR	**VEH^**	**PED^ ``**	**insignificant**	**PED**
c. The most powerful variables against LVR	logfulllinelength^	RED^	nothing	PED

Table 5: A summary of the primary results from the statistical analysis of the eight individual areas; showing the most powerful variables in descending order identified in the stepwise regression of spatial variables against PED, VEH, RED and land value variables

(notes: emb = grid analysed with the embedding; ind = grid analysed without the embedding; conn = connectivity; integ-n/3/7 = radius-n/3/7 integration; diff = difference between embedded and non-embedded syntactic value; LVA96 = log average land value in 1996; LVR = log average rise in land value 1996/88; ^ = negative correlation; " = insignificant correlation)

Evidence can be seen from the relationships between the pattern of retail distribution and grid structure. If the area is made up of small-scale blocks and the grid has both strong edge integration and internal structure, the area is likely to have a high intensity of retail development and, generally, an even distribution of the retail function throughout the grid, i.e., the retail pattern will have a convex structure (Yaowarat and the northern local grid of Bang Lamphu; Figures 2a and b). If the area has an orthogonal and intensive grid structure, but the grid is more globally integrated than locally integrated, it is still likely that the retail function will be developed and distributed in the grid interior. However, the intensity of the internal retail development of this kind of area may be lower than that of an area with a locally integrated grid. This can lead to an uneven distribution of the retail function along the grid lines even though the retail pattern overall may have a convex structure (Banthat Thong; Figure 2c). If the area has strong edge integration but a broken grid interior, the retail function will be mainly developed and distributed along the integrated edges, particularly at the intersection between the most and the second most integrated edge lines. The retail function will rarely be developed internally, but if developed, it is likely to be distributed along the interior lines directly connected to the integrated edge lines, extending from the retail development of the edge lines. The retail pattern will then have a linear rather than a convex structure (Chakrabongse; Figure 2d). If the area has an internal grid structure, whether in terms of a deformed-wheel structure or an internal core line, the retail function will be developed and distributed in the grid interior. However, the intensity of the internal retail development and the structure of the retail pattern will be dependent on the overall integration and layout pattern (orthogonal/broken) of the grid (Nang Leng and Phan Thom; Figures 2e and f). If the area has an integrated grid, but it is made up of large-scale blocks, the retail function is more likely to be developed at the integrated corner, notably at the intersection between the principal global and local integrators of the area's grid, than within the grid interior (Ratchakru; Figure 2g). However, there are also external factors which affect functional specialisation, for example, historic morphology, the morphology of the larger embedding system, the physical impediments causing the truncation of the grid lines or the dominant function of adjacent areas or of the area itself (Surawong 1, which is a CBD area and in which the retail shops have developed within the grid leaving the integrated edge lines for offices; Figure 2h).

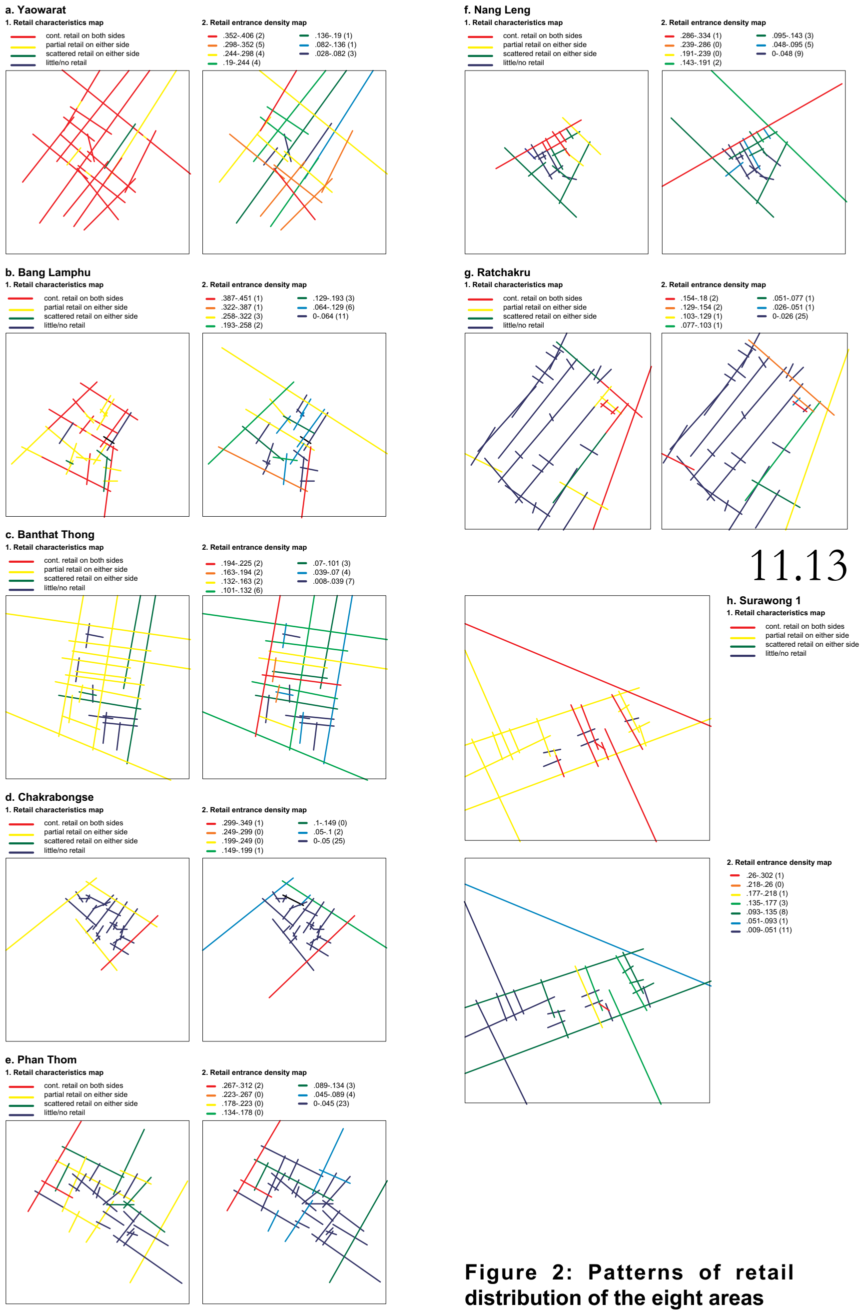

Figure 2: Patterns of retail distribution of the eight areas

Unlike the general spatial conditions referred to by central place theory (close distance to the city centre), the theory of land value (accessibility in relation to the city centre) and the concept of retail affinities (proximity among types of retail store), we have found that the spatial factors which most influence the micro-distribution of the retail function, along the lines or within the areas, are connectivity and radius-3 integration. We also notice that for the areas with an integrated grid, log connectivity is the most influential variable for retail distribution at the line level, while for the areas with a segregated grid, embedded radius-3 integration is the significant variable. Through these results, we can establish that the relationship between spatial structure and functional differentiation develops from the actual layout of the grid as a whole. The relationship is determined by the local grid structure, through the process of centrality (the minimisation of mean trip length) and the movement economy process (the generation of movement within the grid which is taken advantage of by different functions to various degrees). These two processes originate at the major grid lines (major roads) and are then generated through the configuration of the major and minor grid lines.

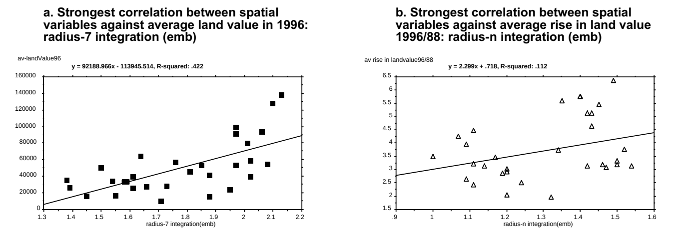

Figure 3: Scattergrams showing strongest correlations against average land value in 1996 and average rise in land value between 1988-1996 of all the 30 areas studied

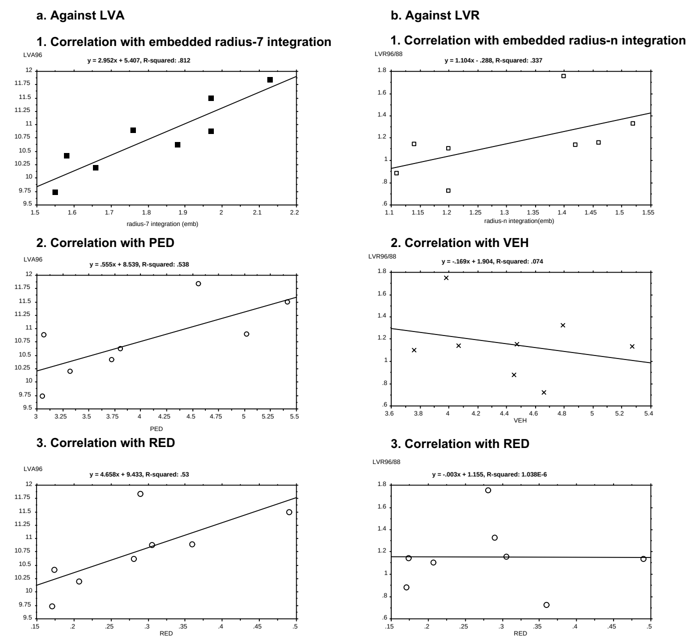

Figure 4: Scattergrams showing three correlation against LVA and LVR in a simple regression of the area level analysis (eight areas combined); with the strongest spatial variable, the strongest movement variable and RED

5. Land-value interaction

Land value was studied in relation to the spatial and functional differences of the four land-use types (from the 30 areas) and in relation to the spatial structure, movement and retail distribution of the areas and the lines (from the eight areas). There were two land-value variables: average land value in 1996 and average rise in land value between 1988-1996. The average land value and average rise in land value of each area were derived from the average value of the lines. It was found that spatial factors are powerful and that the most influential spatial variable on land value overall is embedded radius-7 integration, and on rise in land value is embedded radius-n integration. The more integrated the area, the higher the value and the greater the increase in value. This is true for the 30 areas (Figure 3) and the eight selected areas (at both the area and the line level; Figures 4 and 5). At the line level of individual areas, there are two influential spatial variables on land value and rise in land value: radius-3 integration and connectivity (Table 5).

However, at the line level of both the eight areas combined and individual areas while the spatial effect on land value is positive, its effect on rise in land value is negative (Tables 4 and 5). While the major grid lines are the valuable lines, they have a low increase in land value, whereas it is the reverse for the minor grid lines. Moreover, PED, VEH and RED have a negative correlation with rise in land value for both the area and line levels, and whether the areas are analysed together or individually.

The significant spatial variable for the land value of the commercial areas is non-embedded radius-3 integration (Figure 6). The significant spatial variables for the land value of the residential areas are full line length, which has a negative impact, and embedded synergy (Figure 7). However, for the land value of the mixed-use and CBD areas, the significant spatial variable cannot be identified due to the limited number of cases studied. For the rise in land value of each of the four dominant land-use types, a significant spatial variable cannot be identified.

Overall, both land value and rise in land value are primarily influenced by the spatial structure, established at the outset by the major grid lines. While movement and retail distribution contribute to the value of areas and lines, they are not a great influence on increase in value. These results shed light on the difference in the role of the local and global syntactic factors in relation to the dynamics of retail land-use specialisation, and land value. For retail land-use dynamics, the key is how to create local attractions by the configuration of grid lines through the movement economy process. This in turn establishes the area as a global attraction, through the integrated and intensive local grid

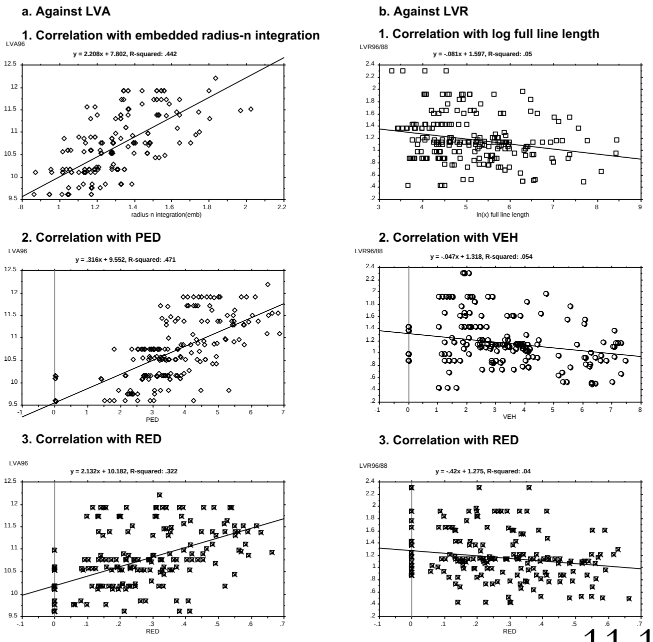

Figure 5: Scattergrams showing three correlation against LVA and LVR in a simple regression of the line level analysis (eight areas combined); with the strongest spatial variable, the strongest movement variable and RED

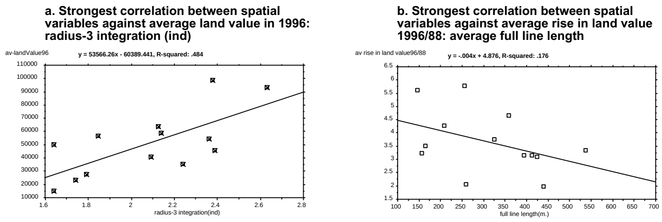

Figure 6: Scattergrams showing strongest correlations against average land value in 1996 and average rise in land value between 1988-1996 of all the 13 commercial areas studied

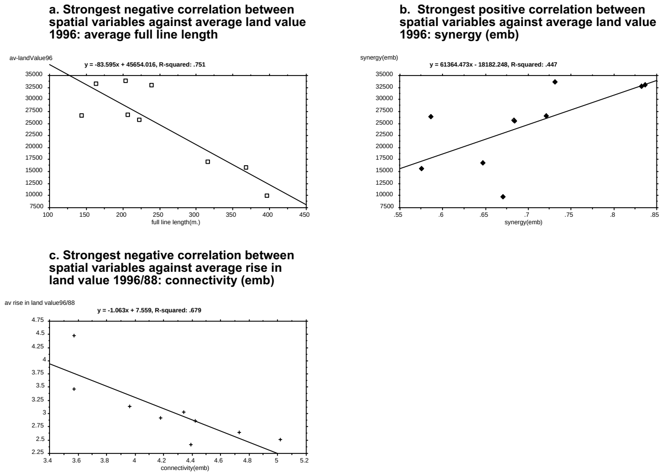

Figure 7: Scattergrams showing strongest correlations against average land value in 1996 and average rise in land value between 1988-1996 of all the 9 residential areas studied

structure, generated by the centrality process, which turns movement across areas into movement within areas. For land value, the key is how the quantity and quality of global attraction is reflected on the land value of an area. Once this is established, the process is repeated at the line level.

The reverse association of the spatial variables and rise in land value between the area and line levels reveals the process of the increase in land value. There is a tendency that land value across areas will increase over time in direct relation to global integration. Once the rise in land value of an area is set by the globally integrated lines (the major grid lines), within the area the value of the less integrated lines (the minor lines) will then increase, in relation to the value of the major grid lines. As the minor lines are less valuable than the major grid lines, the process results in a gradual closing of the gap between the value of the major and the minor

grid lines. Due to this process, the correlation between rise in land value and the spatial variables of the lines in each individual area is negative. The fact that the major grid lines tend to have high movement density and strong retail development explains why rise in land value is negatively correlated with movement and retail variables.

Based on these results, we can state that the distance, convenience and accessibility discussed in land value theories, for example, by Von Thunen (1826), Hurd (1903), Haig (1926), Berry (1959) and Alonso (1964), also work configurationally. Moreover, configurational distance has effects at both the global and the local level. At the global level, configurational distance relates all areas of the city to each other instead of simply relating the other areas to the city centre. The closer the configurational distance an area has to all other areas, the more valuable the area will be and the higher the increase in land value the area will have. At the local level, configurational distance relates the major grid lines (often the most valuable lines) to the minor grid lines (the less valuable lines), that is, the land value of an area is established first by the major grid lines, and then increased by the configuration of the major and minor grid lines, and the minor grid lines have a higher rise in land value than the major grid lines.

6. Conclusion

The results broadly support the hypothesis. There are different spatial structures to accommodate different land-use types, due to the fact that each land-use type benefits to a different degree from natural movement and the effects of the movement economy, i.e., the multiplier effect on movement generated by attractors such as shops. Moreover, the spatial differences between the residential and commercial areas and the consistency of the spatial characteristics of the commercial areas seem to support Hillier's theory of dual socio-cultural and micro-economic process. The micro-economic process which generates the spatial characteristics of the commercial areas remains reasonably constant, unlike the socio-cultural process. Therefore, in order to confirm Hillier's theory we would expect the consistency of the spatial characteristics of the commercial areas to be greater than that of the residential areas. In the commercial areas, the micro-economic process is related to a small-scale block structure and integrated grid, in order to minimise mean trip length and to generate movement within the grid that benefits the commercial function. In the residential areas, the socio-cultural process is generally related to a large-scale block structure and broken grid structure, but it takes differentiated forms. We do not know, however, what exactly these socio-cultural forces consist of, as they can vary in relation to period, taste, degree of security and so on. Nonetheless, in the case of Bangkok we notice two patterns: the history of residential development in a linear fashion along canals[2] and the contemporary development of residential areas inside large blocks with characteristics of the gated community.

The association between grid intensification and commercial grids, which is not only found in the central commercial area of the city (on which Siksna focused), but in all the commercial areas located throughout the city, and the grid configuration of the commercial areas highlight the presence of metric integration and the centrality process, as suggested by Hillier. The centrality process is seen at both the local and the global level. The small-scale block structure and the locally integrated grid structure minimise mean trip length within the grid, in order to generate a strong local movement economy and create locations with movement potential, which attract the development of the commercial function. The globally integrated grid structure and the relatively integrated structure of the surroundings minimise mean trip length from other locations within the city into the commercial areas. This, coupled with the local grid structure itself, makes the area an attractive global location, which in turn can attract more movement at the global level into the commercial area, thereby setting the cycle of multiplier effects on movement at both the local and global level. Moreover, the spatial characteristics of the mixed-use and CBD areas indicate that both types of area develop through the centrality process and metric integration, although to a lesser degree than the commercial type. Thus we can say that any land-use type which benefits from movement, not solely commercial areas, is linked with the centrality process and metric integration, to varying degrees.

Notes

[1] This can be overcome first by a factor analysis to see how far the variables form groups, and second with care in the multivariate analysis to check closely correlating variables against each other and then only inserting the most powerful in the multivariate analysis. For example, the factor analysis highlighted two spatial variables, one to do with the large-scale embedding of the area and the other to do

with the area itself considered in isolation, i.e., non-embedded. When the system was embedded, the less global the variable, the more influential it was on spatial structure; thus radius-n integration, radius-7 integration, radius-3 integration and log connectivity were in descending order of importance as the embedded variable. The reverse is the case for the non-embedded system, where the more global the variable, the more critical it was for spatial structure; that is, radius-n integration was the most important non-embedded variable.

[2] Bangkok began as a canal town around 250 years ago.

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11.18

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