5 Hypothesis of the City with Less Travel

Introduction

The city is a fractal: its structure is fine at any scale. One of the most remarkable characteristics of fractal geometry is its ability to study irregular and natural forms. This is a great leap from urban models to fill the gap of ideal and real cities. To understand the structure and irregularity, fractal geometry uses the hierarchy. We discuss the five dispositions of fractal, referred in chapter 1, as a new tool of thought to materialise and visualise this concept as an attempt to overcome the issues addressed in the earlier chapters.

The current classic, but essential, texts of town planning, such as Jane Jacobs' (1961) *Death and Life of Great American Cities* and Christopher Alexander's (1966) *A City is Not A Tree*, can be read again from fractal viewpoint. 'Fine grain' is now a widely used term in planning which Jacobs (1961) coined in describing a city's component. Many urban designers, including Ian Bentley (Bentley *et al*. 1983) and Peter Calthorpe (1993), have implemented in design (Roberts and Lloyd-Jones 1997).

Special focus will be on the transport system because the system is efficient when its transport form is fractal. Any transport system takes up some space. 70 per cent of the surface area of the city of Los Angels is in some way, such as roads, garages, and parking, dedicated to the vehicles, whilst the blood system in animal's body takes up only 5 per cent. What is remarkable in blood system is, every single cell is no longer than three-cell away from the nearby blood vessels. Because transport system does not produce anything by itself, widening roads means losing the place of production. Production, of course, does not only mean those of industry and manufacture but also creation of society, community, culture and business.

City with Fine Structure

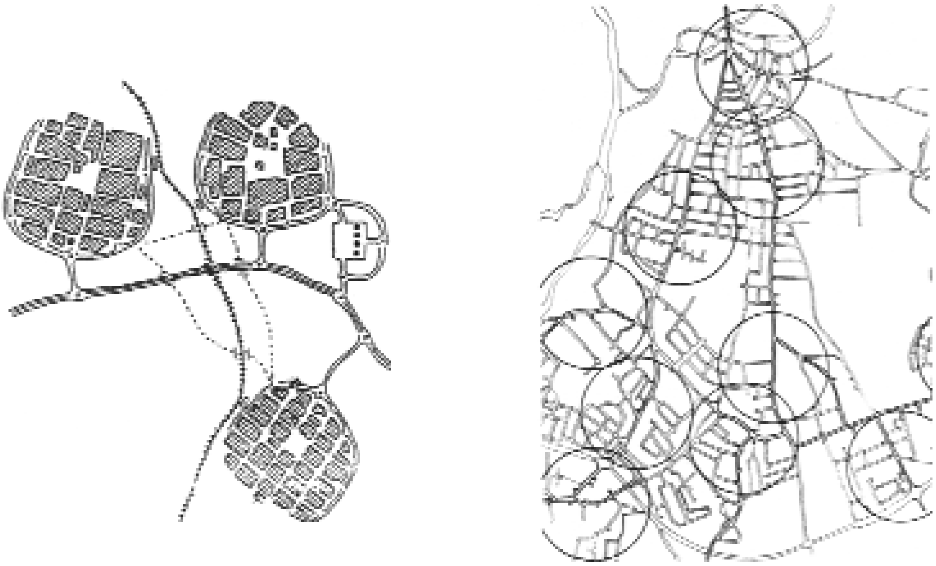
F has a fine structure, i.e. detail on arbitrarily small scale.

In her remarkable book, Jacobs (1961) advocated the importance of streets and neighbourhoods of the city for social vitality. Jacobs' eyes were mere eyes, but with a great insight. She found four principles common in the livable and attractive cities. They are all physical: fine grain of street patterns and road network, mixture of differently conditioned buildings, variety of land-uses and density. Largely influenced by have most academics agreed that development should be based on fairly small neighbourhood units by various groups from transport engineers (e.g. Engwicht 1993) to environmentalists, some of which are reviewed in chapter 3. As Hall (1996) has pointed out, the difference among them is either that cities should be denser and more compact or that they can be dispersed unless jobs are separated from people. However, you will easily notice that they are not necessarily contradictory with each other as long as the concept of 'fine grain' is understood properly.

Of the four essences, 'fine grain' is the most ambiguous word that has misled many urban designers (Figure. 5.1). The most recent and notable one is Urban Village Group's diagram (Aldous 1992). Although each of three urban villages has some fineness within the village, the region supplies only one road, one pedestrian street and one railway linkage to outside. This is because they focus too much on the scale and the village centre and care less on other scales and the edge of the villages. The truly fine structure of transport, at first glance, is more complex.

Let define 'fine structure' of transport in the city: any size of neighbourhood of any point in the city is given as many access opportunities as other places and at other scales.

Peter Calthorpe (1993) has been trying to give physical expression of such idea in the cur-



(a) Segregated Urban Villages (b) An Integrated Part of Fine Structure

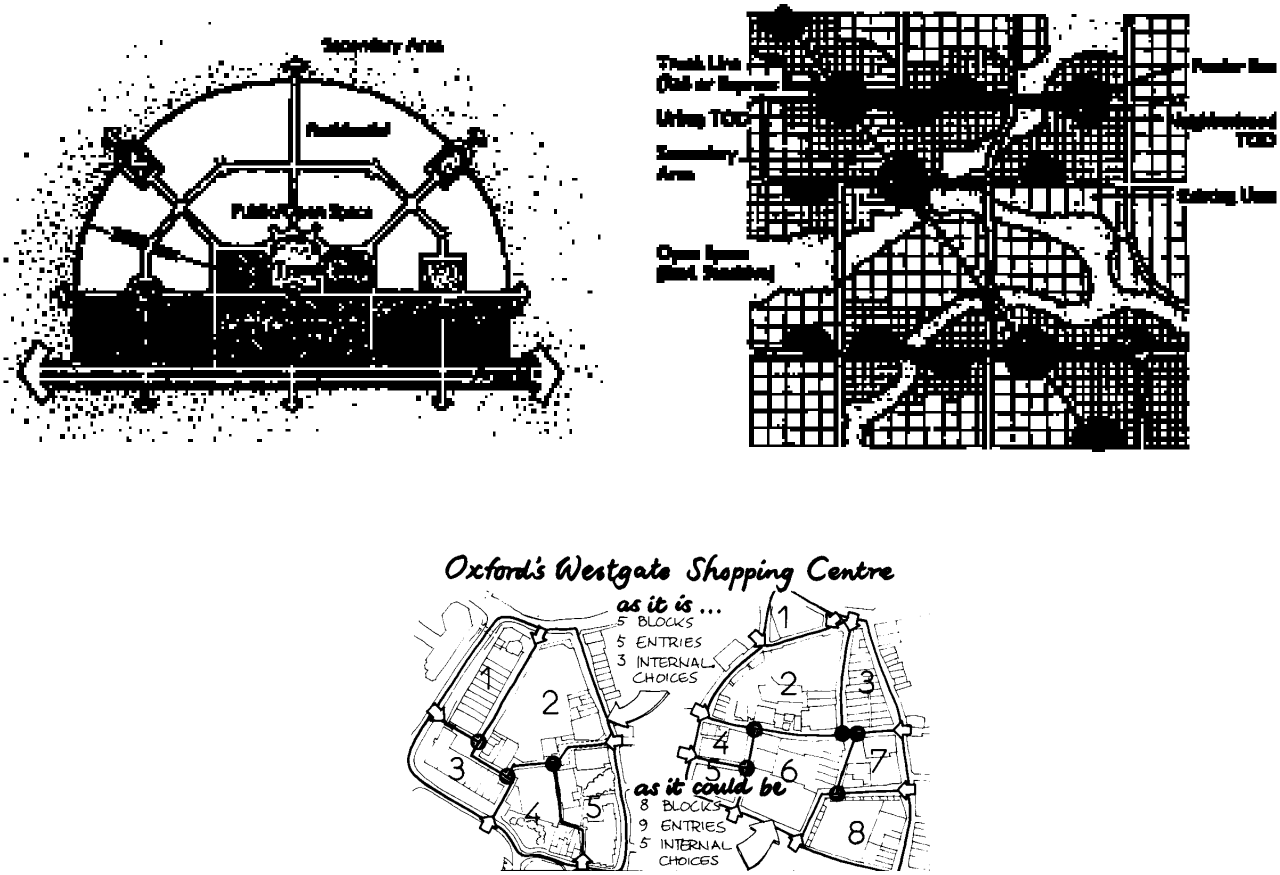
Figure 5.1: The City with Fine Structure

Source: (a) Aldous (1992), (b) Murrain (1993)

rent context of sustainability. His practice is reviewed in chapter 2 and I shall add his theoretical concept in this chapter because it well represents the definition of 'fine structure'. Hall (1996) misunderstood in much the same way as Urban Village Group, mentioning “resulting prescription sounded and looked uncannily like Ebenezer Howard's Social City of 1898”(p.413). He has failed to see what is at other scales such as local and what fills in between the neighbourhood units, that determines the city's fineness, completely missing in Howard's discussion.

In Calthorpe’s TOD principles, a certain minimum proportion of uses is always required to stimulate pedestrian activity and to provide economic incentives for developing with mixed-use patterns. As a result, every TOD should have public space (5%-15%), core/employment space (10-70%) and housing (20-80%), none of which exceeds 80%. What should be emphasised, especially compared to Howard’s Social City, is this mixture of uses be achieved within walkable distance (Figure 5.2a).

Bentley *et al.* (1985) has discussed in a different way to achieve ‘responsive environment’



(a) Transit Oriented Developments (above left and right) both give ample examples of fine structure at varied scales from personal to regional. (b) Responsive Environments (above)
Figure 5.2: Designing Fine Structure
Source: (a) Calthorpe (1993), (b) Bentley *et al.* (1985)

(Figure 5.2b). Figure 5.2a shows an example to increase ‘permeability’ and make smaller blocks by creating more junctions. Also seen in the figure are legibility and robustness issues: combining the landmarks and nodes makes the city more legible, while longer over-all streets with shorter blocks have people use the space more, and thus create a secure community.

Irregularity, non-linearity and efficiency

> ***F*** is too irregular to be described in traditional geometrical language, both locally and globally

The design of a place affects the choice at many levels. Figure 5.1 shows an example of two

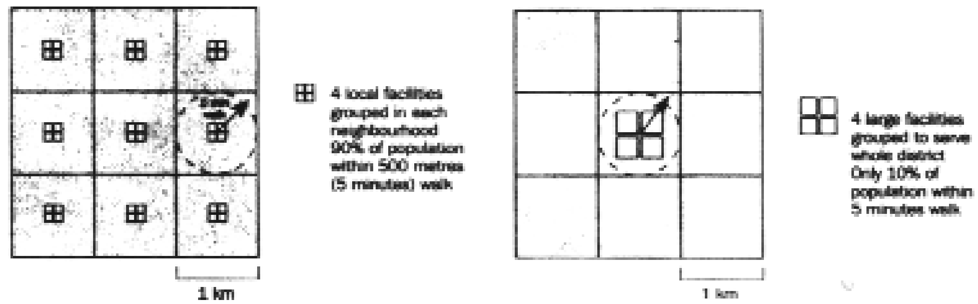


Figure 5.3: Locational Optimisation of Facility
Source: DoE (1995)

possible design solutions of a shopping centre in Oxford. With the increasing segregation of activities, journey lengths are increased (Banister *et al*. 1994). As reviewed in chapter 2, Calthorpe's (1993) concept is to bring, in the walkable distance, as many uses as possible. A successful town may offer services as many as 90% of its residents, while a badly planned can do only 10%. The figure in Better Practice Guide, appended to PPG13, brought remarkable characteristics into sharp relief (Figure 5.3). A district with nine smaller facilities are preferred to a district with one large facility because only 10% in the district are in the walking vicinity. One of the common misunderstanding of this fine structure is to segregate these towns from one another (Murrain 1993, Figure 5.1).

One of the criticisms of urban models is its incapability of irregularity. A place has a function. But irregularity adds extra to the place. This is an essential component of fine structure. Irregularity to our eyes, indeed, can be categorised into two: disorganised complexity and organised complexity. The focus here is on the latter as it is the most efficient form in the nature.

In general, many unintended actions occur at the edge of two different things. Watching other people, for example, is an important component to keep the street safe (Jacobs 1962). This mostly happens at the edge of the space, which offers a sense of refuge as well as a prospect of what is going on (Bentley *et al*. 1986). Although cities are finite in space, these edges can be infinite, and at that time, the city is robust. The more safe is the street, the more people enjoy walking and more attractive will be the street. Irregularity gives more edge to

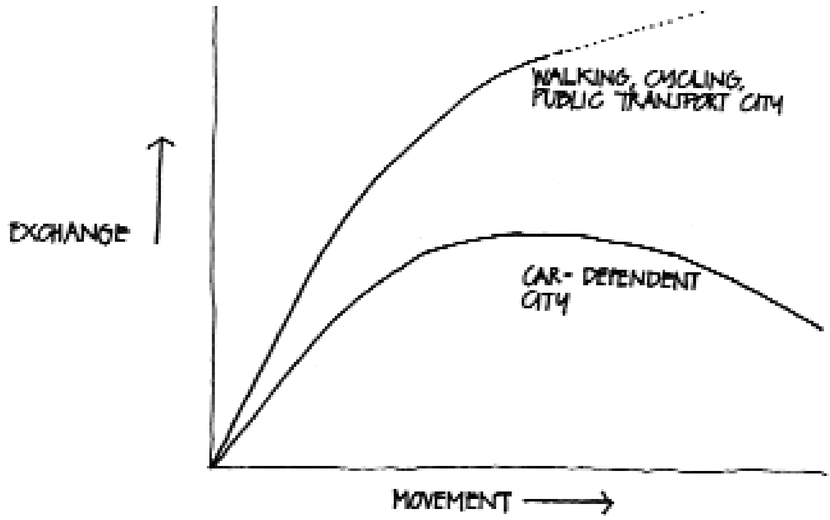


Figure 5.4: Optimum Point of Exchange Efficiency for Two Types of Transport Systems
Source : Engwicht (1993 p.129)

the city.

Another feature of irregularity is its efficiency. The current economy, however, has pursuit the amount of exchange, rather than the efficiency. To some extent, the amount and the efficiency grow simultaneously (Figure 5.4). But in the current situation that road and vehicle-related uses occupy more than 30% of the urban area, the efficiency does not cope with the amount. In mathematical words, it is said as follows. At an optimum point of road space area, the exchange rate reaches the highest. Over the point, therefore, the exchange efficiency will reduce because the cross commuting brings about unnecessary travel. Consequently, commuting patterns in Sydney, Melbourne Adelaide and Perth, cross-commuting doubles the amount of travel really necessary, and because converting dual-purpose exchange/ movement space to exclusively movement space erodes exchange opportunities and demands the city spread (Engwicht 1992).

He implies that, at the optimum point, the road network takes fractal form. In other words, the efficiency grows with the fractal dimension of the city's road network. And it is possible to describe the way to make it more fractal. In most cases, the urban model has some form that of Garden City, Rickaby's settlement patters or Transit Oriented Developments. What makes it fractal does not only depend on these patterns (generator) but also on that the pattern should appear at any scale and at any place. For example, most cities have their central business districts (CBDs), and the city's efficiency rises when every smaller district has their secondary CBDs, no matter how smaller districts are defined. The form of CBD is, in this case, the generator of the fractal. It is therefore important to identify the generator. The mathematical analysis of optimal form gives us the answer of the form to which the average length from the points in the space can be minimised. On the contrary, the simple forms such as rectangulars and circles are the least efficient. To make it simple, the city is assumed to consist only of developed areas and roads and its settlement density is homogeneous in the developed areas. It is practical that the roads occupy a certain area of the city but less road area is preferred not to lose the developed areas because they are the place of business and residence. In addition, the demand of road is also homogeneous and the distance to the road network from any point in the developed area is measured in Euclidean metric way. In this way, how to locate the road network in the city is solved by a mathematical analysis of locational optimisation for multi-polygonal spatial facility. In the analysis, another assumption may involve the upper limitations of facility perimeter for technical reason. The limitation is then relaxed to show the 'real road network to minimise the distance to the road network.

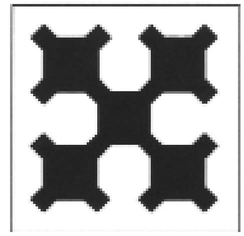
The road network is, in this analysis, assumed as a polygon $\boldsymbol{P}$ which consists of $\boldsymbol{n}$ sides, $(\mathbf{x}_1\mathbf{x}_2\mathbf{x}_3\cdots\mathbf{x}_n)$. The question is now a non-linear mathematical analysis with a given area and perimeter. The smallest distances of a point $\boldsymbol{x}$ to another point $\boldsymbol{x}_i$ and a line $\overline{\mathbf{x}_i\mathbf{x}_{i+1}}$ are $||\mathbf{x}\text{-}\mathbf{x}_i||^2$ and $d(\mathbf{x},\mathbf{x}_i\mathbf{x}_{i+1})^2$ respectively, and thus the question is expressed:

$$\min_{\mathrm{x}_1\cdots\mathrm{x}_2}\left[\sum_{i=1}^{n}\iint_{\mathrm{V}(\mathrm{x}_i)} f(\|\mathrm{x}-\mathrm{x}_i\|^2)dxdy+\sum_{i=1}^{n}\iint_{\mathrm{V}(\mathrm{x}_i\mathrm{x}_{i+1})} f(d(\mathrm{x},\overline{\mathrm{x}_i\mathrm{x}_{i+1}})^2)dxdy\right] \qquad (5.1)$$

where the limitations of area and perimeter are

$$S \le \begin{cases} \frac{1}{2}\sum_{i=2}^{n}(x_i-x_1)(y_{i+1}-y_{i-1}) & (n=2k+1) \qquad (5.2) \\ \frac{1}{2}\sum_{i=2}^{n/2}(x_{2i-1}-x_1)(y_{2i}-y_{2i-2})(x_{2i}-x_2)(y_{2i+1}-y_{2i-1}) & (n=2k) \qquad (5.3) \end{cases}$$

Figure 5.5: Mathematical Optimisation of Form to Minimise the Traffic Demand
Source: Shiode (1995)



The solution of this nonlinear analysis gives us an optimum form of facility (Figure 5.5). As the boundary length increases and the area decreases, the form look like a star-shaped, or in our terms, fractal. If the length restriction is infinite, then the form will 'fill' the area.

Robustness and Hierarchy in the City

Often ***F*** has some form of self-similarity, perhaps approximate or statistical.

There is a myth that a city should have a hierarchy, but what for? On the contrary, the city should have less hierarchy. More precisely, the less is the differences at two adjacent levels, the more robust is the city. The city has several sets of hierarchy, if intended or not. Road hierarchy, for example, consists of main roads, distribution roads, local streets and those only kids know. They are created by their users and modified, as the users need change. In the most robust road network, however, the differences are subtle so that lower level roads are able to accommodate in the case of accident.

In a thin hierarchy, on the contrary, real problems of accessibility are found. Since 1900s has occurred thinning of hierarchy (Short 1996). Thereafter, "paved roads and automobile use allowed consumers to bypass smaller centers. As the small store is replaced by the out-of-town shopping center and as hypermarkets provide better bargains than the neighborhood grocery, then the provision of goods moves up the hierarchy. Smaller centers lost some of their vitality" (Short 1996 p.64-65). Despite their resemblance in theory (Hall 1996), there-

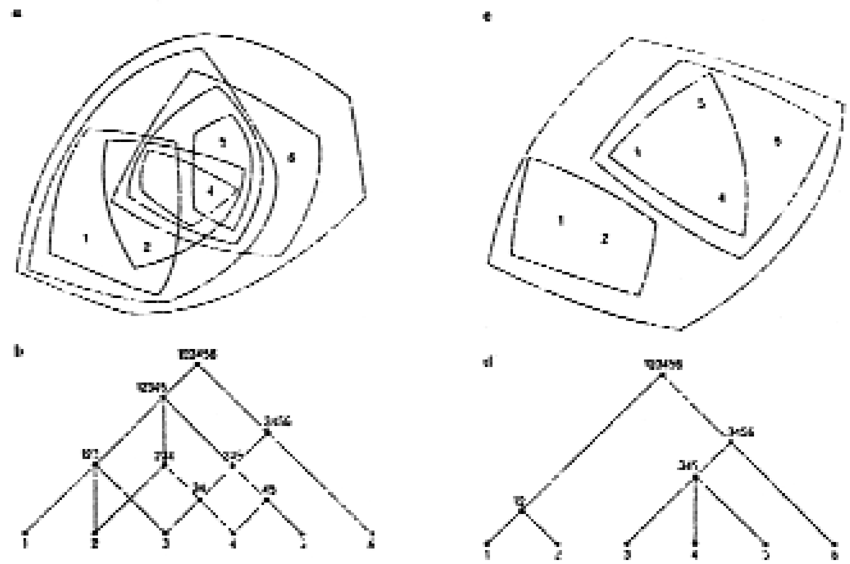


Figure 5.6: Hierarchy Diagram
Source: Alexander (1961)

fore, Calthorpe's bottom-up approach is more versatile than Howard's top-down thinking.

Capra (1982) has also pointed out

> The traditional symbol for these (hierarchy) structures has been the pyramid. By contrast, most living systems exhibit multileveled patterns of organization characterized by many intricate and nonlinear pathways along which signals of information and tradition propagate between all levels, ascending as well as descending. (p. 305)

In reality, the hierarchical planning has been deteriorating the city because it has led to zoning that divides the city into segregated parts to inhibit diversity of exchange (Engwicht 1993). This is because the boundary of areas with different land uses, or the interfaces between these function, is greatly diminished by zoning (Bentley *et al.* 1985). The city, its every street and every neighbourhood, therefore, must be the city in microcosm, reflecting the full diversity of the city, then a richer range of exchange is facilitated.

Alexander (1966) has given us a diagram to help us understand this (Figure 5.6), which is quite compatible with the definition of 'fine structure'. No matter where you are, you have more choices, thus more permeable, in fractal city (Figure 5.6 a and b) than model city (c and d).

Fractal Dimension of the City

> Usually, the fractal dimension of F (defined in some way) is greater than its topological dimension.

The concept of fractal in town planning is to visualise the city's fine structure. The concept of fractal dimension is, on the other hand, to enumerate the extent of irregularity and hierarchy so that city's fineness can be compared. Symbolically, rather than mathematically, it can be expressed as:

Fractal Dimension = Irregularity / Hierarchy (5.4)

which implies that a structure with high dimension has a fine structure. In the basic principle, fractal dimension (D) is defined:

$$D = \log N / \log r \qquad (5.5)$$

where r scaling ratio and N the number of subsets. In Figure 5.3, for example, the DoE's proposal of nine smaller facilities has higher dimension, assuming that the facilities are further divided into 9^2 smaller facilities, which are divided into 9^3 smaller facilities. Although the scaling ratio is not defined in Figure 5.3, it is likely that D will have higher dimension than 2.

Let us take Rickaby's (1981, 1987) six (actually five) settlement patterns (Figure 3.3). This comparison is useful because energy demands have already been estimated. The patterns are: Pattern 0 is the original archetypal pattern with single town centre with rural hinterland. Pattern 1 is concentrated nucleated, pattern 2 is concentrated-linear configuration, pattern 3 is dispersed-nucleated (satellite towns), pattern 4 is dispersed-linear configuration and pattern 5 is dispersed-nucleated (villages).

The estimation method is discussed in chapter 6 in detail. Here it suffices to say that the fractal dimension can be defined to various objects in the city. The fractal dimensions of settlement distribution and road network are show in table 5.7 for Rickaby's six settlement patterns. The result gives us some hints. The settlement patterns with higher fractal dimension of inner population (patterns 1, 3 and 5) tend to be more efficient. This is most remarkable in med scenario.

Rickaby simulated energy consumption in six different settlement patterns. Pattern 0 is the original, fairly concentrated city and all the rest are development options based on pattern 0. In the pattern 1, the development is only in the brownfield for higher density. Patterns 2 and 4 are linear developments, 2 along several radial and 4 along several radial and angular directions. Patterns 3 and 5 are planer, 3 with some medium satellite towns while 5 with smaller villages. Table 5.7 shows the estimation by Rickaby and fractal dimensions of population and raod for each settlement. The estimation method is based on Benguigui and Daous (19xx), which will also be used and exaplined in detail in the following chapter.

There is a tendency, in all the patterns, that the fractal dimension vary significantly between in inner city and in outer city, which cannot be found in the existing cities in the following chapter (Table 6.5). This is due to oversimplification of 'inner' and 'outer' area and thus none of these settlements reflects the reality. In table 5.7, the estimated fractal dimensions both for inner and outer areas are shown. In inner area, as in the real cities, the fractal dimensions fall within the range between 1 and 2, which means it is planer (two-dimensional), while the outer area, linear (one-dimensional). Although they are in a reality range, the inner road fractal dimensions are approximately 1.2 in all the settlements, which is quite low compared to many real cities. This will cause a confusion in the latter discussion and policy-making of ideal settlement, if any, towards less energy-demanding city.

The pattern 1 is the intensification of brownfield areas, which does not only result in higher density in the inner area but also in higher fractal dimension. This is because the develop-

Pattern	0	1	2	3	4	5
Energy Consumption						
High scenario	8672	6591	7885	7011	7244	7244
Med scenario	6140	4601	5382	4739	5228	4999
Low scenario	4529	3405	3826	3367	3796	3714
Fractal Dimension						
Population (Inner)	1.79	1.83	1.21	1.86	1.21	1.86
Population (Outer)	0.37	0.01	0.56	0.17	0.57	0.21
Road (Inner)	1.24	1.17	1.21	1.18	1.21	1.23
Road (Outer)	0.54	0.47	0.56	0.4	0.57	0.55

Table 5.7: Fractal Dimensions of Rickaby's six settlement patterns

ment is intensed more in the outer area of inner city. As there was little development outside the inner area, the fractal dimensions in the ouwer area will be smaller.

In the patterns 2 and 4, some population in the inner city moved to outer area. Pattern 2 is developed along several radial directions while patter 4 along radial and angular directions. In terms of fractal dimension, there is not much difference between them and between them and the original settlement since the developments are both linear (one-dimensional).

The patterns 3 and 5 are the attempts to disperse the population homogeneously in the city and thus gives the highest fractal dimensions particularly in the outer area. However, because of the models' oversimplification, the both developments remain linear with fractal dimension less than 1, which is unrealistic. Be definition of fractal dimension, the number of satellites divided by scaling ratio, the difference of the patterns 3 and 5 are subtle.

Generating the Fractal City

> In most cases of interest ***F*** is defined in a very simple way, perhaps recursively.

It is not a difficult procedure to create a fractal image. You need an initial object and a motif called *generator*. If generator is applied to the structure at every scale and at every place, it will be a fractal. Applying the generator once again at this new scale results in a further elaboration of the design at yet a finer scale, as if you see the fine detail of a cathedral, and this process is continued indefinitely towards the limit.

An example of generator is, in town planning, development which can be controlled to make the city fractal. There are many patterns of generators, including the current development patterns. However, once a generator of sustainable development is integrated into development control, the efficiency of sustainable development will be maximised.

Possible generators are Calthorpe's TOD and Bentley *et al.*'s design principles. Adopting TOD in Figure 5.8, the surrounding areas with less housing, less retail, less open space and less public transport are all given the opportunity to solve their problems, without compromising the development area's benefit. In a sense, this looks like the agents work in a cellular automata model With this method, the developments in the city proceed gradually to improve the city's overall mixness.

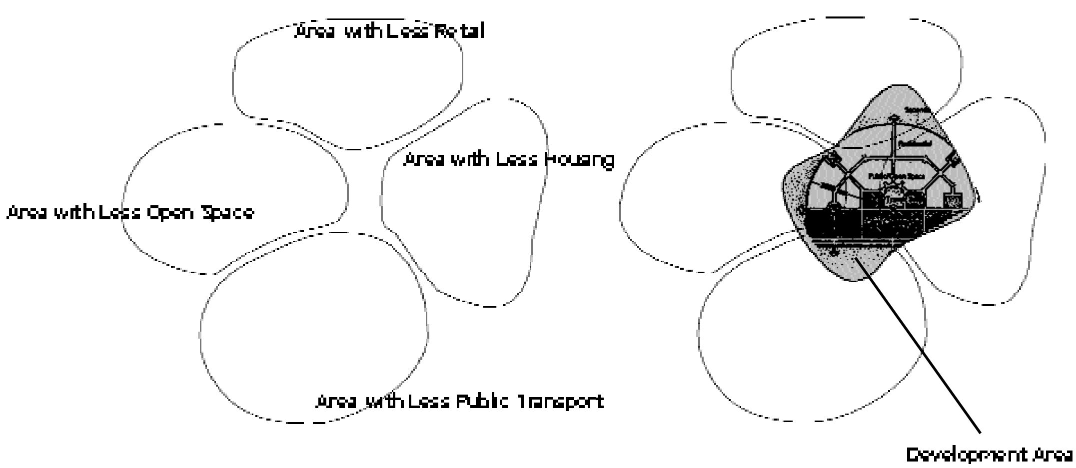


Figure 5.8: Adopting Generator in Development