

Chapter 2

The First Culture of Cities

The *quantitative revolution* was an attempt made in the 1950s by a new generation of urbanists to transform the “soft” descriptive study of cities into a “hard” analytical science (Burton 1963). These urbanists have revolutionized the field mainly by adopting location theory – a group of theories developed since the mid-19th century, mainly by economists who added *space* into the otherwise ‘spaceless’ economic models, and settlement geographers who employed economic consideration and physical analogies as means to explaining settlement patterns. The “founding father” of location theory and by implication of the quantitative revolution, was the 19th century German economist Johann Heinrich von Thünen with his *Isolated State* and our story begins with him. I write “founding father” in brackets because economist Thünen will never know that some 120 years after publishing his *Isolated State*, his work has become the foundation for a new theory of cities and settlements.

2.1 Thünen’s Isolated State

Imagine a very large town at the centre of a fertile plain, which is crossed by no navigable river or canal. Throughout the plain the soil is capable of cultivation and of the same fertility. Far from the town, the plain turns into an uncultivated wilderness, which cuts off all communication between this State and the outside world.

There are no other towns on the plain. The central town must therefore supply the rural areas with all manufactured products, and in return it will obtain all its provisions from the surrounding countryside.

The mines that provide the State with salt and metals are near the central town which, as it is the only one, we shall in future call simply “the Town” (Thünen’s *The Isolated State*, Chap. 1, Hypotheses.)

The problem we want to solve is this: What pattern of cultivation will take shape in these conditions, and how will the farming system of different districts be affected by their distance from the Town? We assume throughout that farming is conducted absolutely rationally.

It is on the whole obvious that near the Town will be grown those products, which are heavy or bulky in relation to their value, and hence so expensive to transport that the remoter

districts are unable to supply them. Here too we shall find the highly perishable products, which must be used very quickly. With increasing distance from the Town, the land will progressively be given up to products cheap to transport in relation to their value.

For this reason alone, fairly sharply differentiated concentric rings or belts will form around the Town, each with its own particular staple product.

From ring to ring the staple product, and with it the entire farming system, will change; and in the various rings we shall find completely different farming systems. (Thünen's *The Isolated State*, Chap. 2, The Problem.)

These two short chapters that open von Thünen's *The Isolated State in relations to agriculture and political economy* is a verbal description of *The Isolated State* – the model which provides the foundation to all his economic work. "This method of analysis", he writes:

has illuminated and solved so many problems in my life, and appears to me capable of such widespread application, that I regard it as the most important matter contained in all my work" (Hall, introduction to Thünen 1996, XXII).

At a later stage, so writes Thünen in an appendix to his book, this model was translated by a friend into the diagrams presented in Fig. 2.1. And despite Thünen's

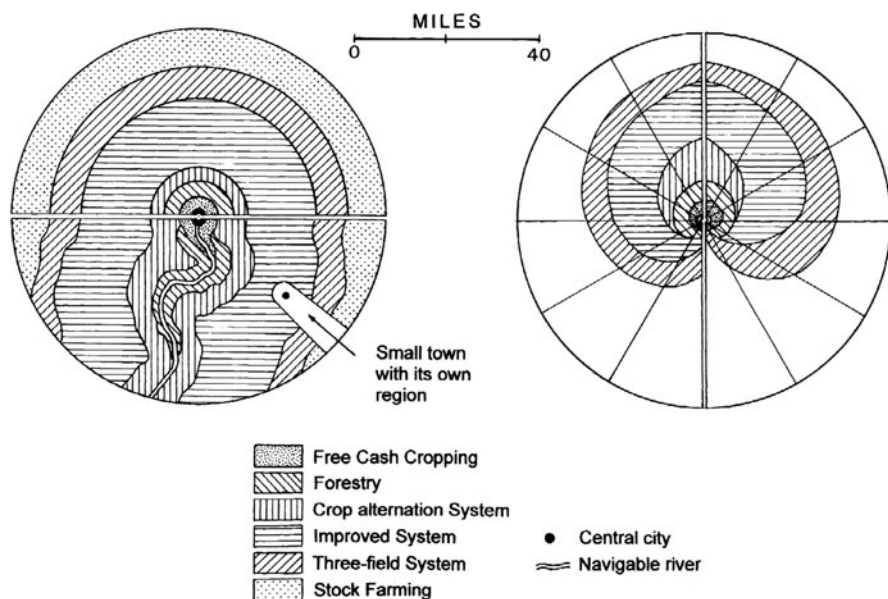


Fig. 2.1 "These diagrams", writes Thünen (Par. 384), "drawn by a friend of mine, are not essential to an understanding of the problem under discussion—and nowhere in the work have I referred to them. But since they afford a simple and survey, . . . I feel they might be welcome to the student . . ." (Top, Left) "This shows the Isolated State in the shape it must take from the assumptions made in Section One . . .". (Bottom, Left) "Here we see the Isolated State crossed by a navigable river. Here the ring of crop alternation become very much larger, stretching along the river . . . The effect of constructing a highway is similar, . . ." (Par. 385). (Right) "The diagram illustrates the effect of the Town grain price on the extension of the cultivated plain" (Par. 386)

comment that these diagrams “are not essential to an understanding of the problem under discussion – and nowhere in the work I have referred to them”, they have since become the symbol/icon of his work – at least among students of geography, location and urbanism (especially Fig. 2.1a). Due to his *The Isolated State*, Thünen is regarded as the most important German economist of the 19th century; first, because it is the first formal economic model, and second, since Thünen has unconsciously invented here the economic principle of *marginalism*, some 50 years before Léon Walras, Carl Menger and William S. Jevons have made it the basis for modern economic theory (see Portugali 1984, for further discussion and bibliography).

2.1.1 The “Isolated City”

As noted above, due to his *The Isolated State*, Thünen is also regarded as the founding father of modern location theory; first, because his model enfolds all the ingredients of this theory – isotropic plane, spatial competition between land uses and the principle of marginal spatial utility – and second, and as a consequence of the above, since by changing a few key words in his verbal model, one can get the standard urban land-use model as formulated some 100 years later by the economic land use theorists of the city:

Imagine a very large CBD (Central Business District) at the center of an urban plain, which is crossed by no navigable river, road or canal. Throughout the plain the urban land is capable of all land uses and with the same utility. Far from the CBD, the plain turns into wilderness, which cuts off all communication between this metropolis and the outside world.

There are no other centers on the plain. The city center must therefore supply the other urban areas with all urban products and services, and in return it will obtain all its labor force from the surroundings.

The mines and factories that provide the Metropolis with raw materials and industrial products are near the CBD which, as it is the only one, we shall in future simply call “the Center”.

The problem we want to solve is this: What pattern of land use will take shape in these conditions?; and how will the urban system of different districts be affected by their distance from the Center? We assume throughout that decision-making is conducted absolutely rationally.

It is on the whole obvious that near the Center will be allocated those land uses which are sensitive to the distance from the Center to the extent that they will not be supplied if located far from it. Here too we shall find services and products, which require an exposure to a very high threshold of potential customers in order to be supplied. With increasing distance from the Center, the land will progressively be given up to land uses cheap to transport in relation to their value.

For this reason alone, fairly sharply differentiated concentric rings or belts will form around the Center, each with its own particular land use.

From ring to ring the land use, and with it the entire metropolitan or urban system, will change; and in the various rings we shall find completely different land use systems.

Similarly to von Thünen's friend, we too, can transform this verbal model into a visible diagrammatic model. All we have to do for this purpose it to take

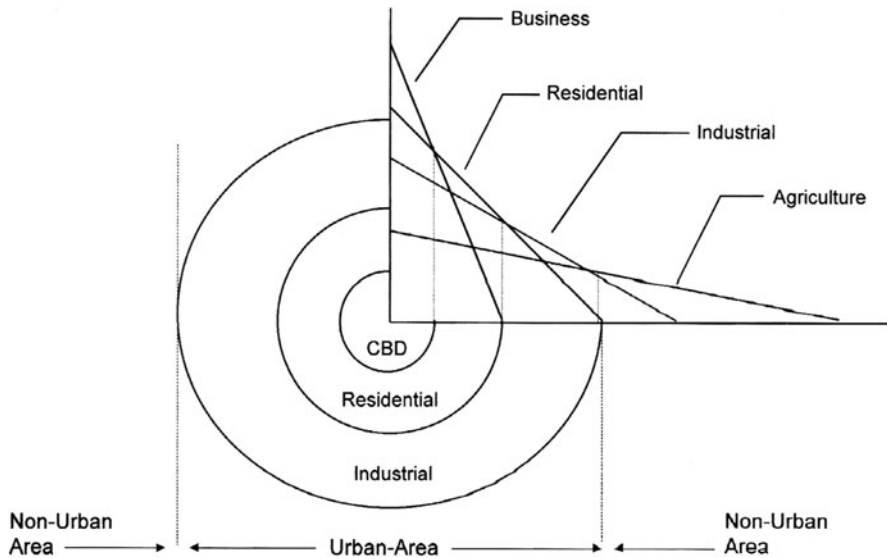


Fig. 2.2 Thünen's type urban land-use system as derived 100 years later in location theory by Alonso (1964). Businesses are prepared to pay high rent at the center of the city, but are reluctant to "live" far from it. Their spatial demand curves (or rbc – rent-bid curves) are thus the highest and steepest. Industrialists, in this exposition, are exactly the opposite and residents are in between: they cannot afford to pay the high prices at the center, but are prepared to live far from it, and so on. Each land use thus occupies a ring where it can pay (bid for) the highest rent. Note that the principle of marginal utility which is implicit in Thünen's landscape, here appears explicitly as the central economic principle. The resulting spatial pattern is as in Thünen's, however

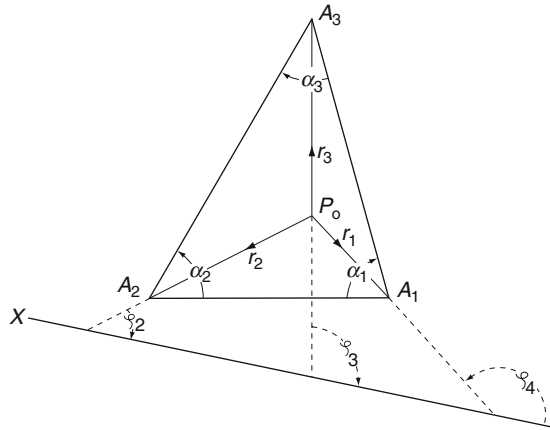
the standard image and model of a city as formulated in location theory. The latter is usually derived not verbally, as in Thünen's, but by means of interplay between spatial demand curves and rent-bid curves as in Fig. 2.2. This play between spatial rent-bid curves was suggested by Alonso (1964) and is often termed *bid-rent theory*.

2.2 The Best Location

Unlike Thünen who unintentionally and unconsciously became the founding father of location theory, Alfred Weber, the young brother of the famous Max Weber, was the first to produce an explicit theory of location for its own sake. In the introduction to his major work *Theory of the Location of Industries* (Weber 1929/1971) he writes the following:

"We have a theory of the location of agricultural production by Thünen, . . . But we do not as yet have any theory of the location of industries . . ." (p 5–6)

Fig. 2.3 Weber's (ibid Fig. 44) locational triangle. A_1 and A_2 indicate the location of the two raw materials (e.g. mines) needed to produce a given product; A_3 is the location of the city where the end product must be sold/consumed. P is the location of the production point (e.g., a factory), while r_1 , r_2 , and r_3 are the distances from P to A_1 , A_2 , and A_3 , respectively



Similarly to Thünen, he starts to formulate his theory with an imaginary uniform plain isolated from the rest of the world. “Methodologically”, he writes, “we shall always proceed by isolation” (p 10). However, unlike Thünen who starts from a single point in space (“imagine an isolated town . . .”), Weber starts with an isolated region within which there are three points/locations that are essential to the production of a certain industrial product: Two points (e.g., mines) that supply the raw materials needed to produce the product and a city where the end product must be sold/consumed. These three points define what Weber (p 49) calls the *locational figure* and *locational triangle* (Fig. 2.3). Given the locational figure, the

“... problem to be solved is how transportation costs influence the distribution of industries, assuming that no other factors influencing the location of industries exist.” (Weber, ibid, p 41).

It is clear that in such circumstances the production point must be located within the location triangle; the question is where? Weber answers in two steps: First he says, the production point must be in a location that minimizes transportation costs of the raw materials from the mines to the production point and the end product to the market. Metaphorically this can be likened to “an old apparatus invented by Varignon . . .” (ibid 229) that is shown in Fig. 2.4.

Second and at a more general level, the location of the production point is determined by means of what Weber has termed the *material index*, which is the ratio of weight of intermediate products (raw materials) to finished product. The material index gives indication as to whether the optimal location point will be close to the sources of raw material or close to the market, that is, to the city.

Equipped with these locational tools Weber turned to study several phenomena, in particular the phenomenon of agglomeration and the impact of labor. In both, the basic question is the same: in what circumstances the industry (i.e. the production point) will move from its optimal location inside the location triangle toward other industrial installations (agglomeration) or toward another location (e.g., a city or

Fig. 2.4 Pierre Varignon (1654–1722), a French mathematician, played a role in elaborating Newton's law of gravitation. His studies paved the way for the discovery that moments of forces are axial vectors. He illustrated this, among other things, by means of what became known as the *Varignon's apparatus*

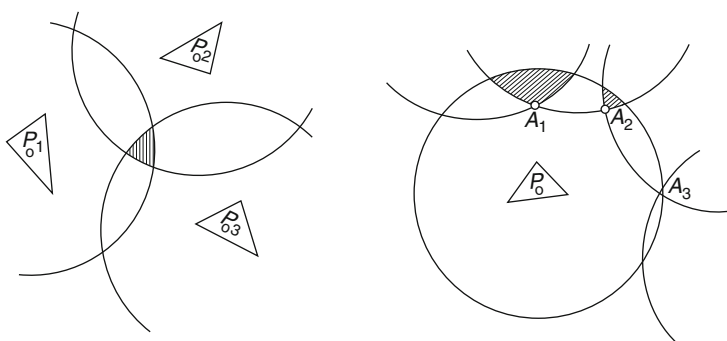
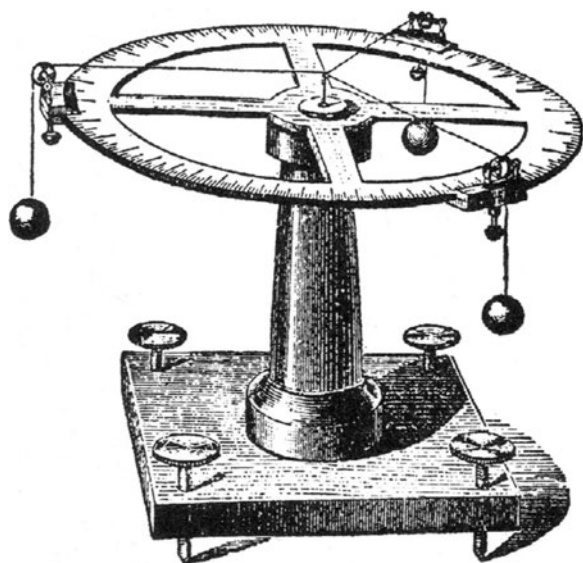


Fig. 2.5 Weber's (ibid Figs. 20, 21) illustration of agglomeration. As can be seen, it occurs when due to internal and external economies, industries prefer to move away from their optimal location (as determined by their location triangle) and to spatially concentrate in an intermediate locale. "The center of agglomeration must obviously lie within the common segments of the critical isopodanes [lines indicating the cost of moving the production point away from its optimal location] . . . It will be located at the one of several possible points.. which has the lowest transportation costs in relation to the total agglomerated output" (Weber 1929/1971, p 138). Thus, the intersection between the three isopodanes will entail agglomeration (Fig. 2.5, left), while the two intersections in Fig. 2.5, right will not

country) that provides cheaper labor. The principle answer to both is identical (see Figs. 2.5): Movement from the optimal location entails increase in transportation costs. Consequently, the move will be implemented if the increase of transportation costs is less than the benefits from the new location – economies of scale in the case of agglomeration and the saving on labor costs in the case of labor.

Similarly to Thünen's agricultural land-use theory, Weber's industrial location theory was not formulated as an explicit urban theory and similarly to Thünen's theory, the urban component was from the start implicit in it. Firstly, in the sense that following the industrial revolution, the location of industries and the phenomena of agglomeration were one of the attractors to the process of urbanization. Secondly, since the processes of labor migration to industrial countries, regions and cities and the migration of industries to locations of cheap labor are major urban phenomena and forces, specifically so today, at the age of globalization.

But there is a third property of Weber's theory that makes it urban and was not given attention, and it is this: Weber, as we've seen above, considered his theory as complementary to Thünen by adding industry to agriculture. However, Weber is complementary to Thünen in yet another and more general locational respect. Thünen's basic question was this: given a locational point in space (the city) how do we arrange the various land-uses around it? Weber's is the symmetric mirror image of Thünen's: given an area within which various elements are spatially distributed, where is the best locational point? Weber in his theory considered the best location for an industry, but the question and the answers are in principle more general and can refer to the best location for a shopping center, an airport, a neighborhood, and of course, a new town or a city.

2.3 Cities as Central Places

Thünen's concentric rings image of the city was a source also to another image of the city, or rather of cities: cities as central places for their agricultural hinterlands, cities as mediators between their hinterlands and other cities, and cities as hierarchical systems of central places. *Central Place Theory* was developed independently by two persons: Christaller (1933/1966) in his work on *The Central Places of Southern Germany*, and August Lösch (1954) in his *The Economics of Location*. If Thünen has "invented" the notion of marginal utility some five decades before its time, then Christaller and Lösch have suggested a genuine system theory several decades before Bertalanffy (1968) published his *General System Theory*.

Both Christaller and Lösch start with an "isolated city" of a sort. Christaller starts with a kind of an isolated state, which includes a geometrically central city and its dependent peripheral towns. From this starting point he then derives three basic hierarchies of central places (the $k = 3$ market, $k = 4$ transportation, and $k = 7$ administrative principles) from which the population of this imaginary state can consume goods and services and in which they can sell the products they produce. This is illustrated in Fig. 2.6. Lösch, on the other hand, starts with several independent isolated states, or cities, floating on an isotropic plane. He then assumes an increase of population and economic activities which bring in more isolated cities, then by means of competition and general spatial equilibrium, the whole region becomes full and at a later stage as the process continues it reaches a spatial equilibrium in the form of a complex system of central places. Figure 2.7 describes the main stages in the process.

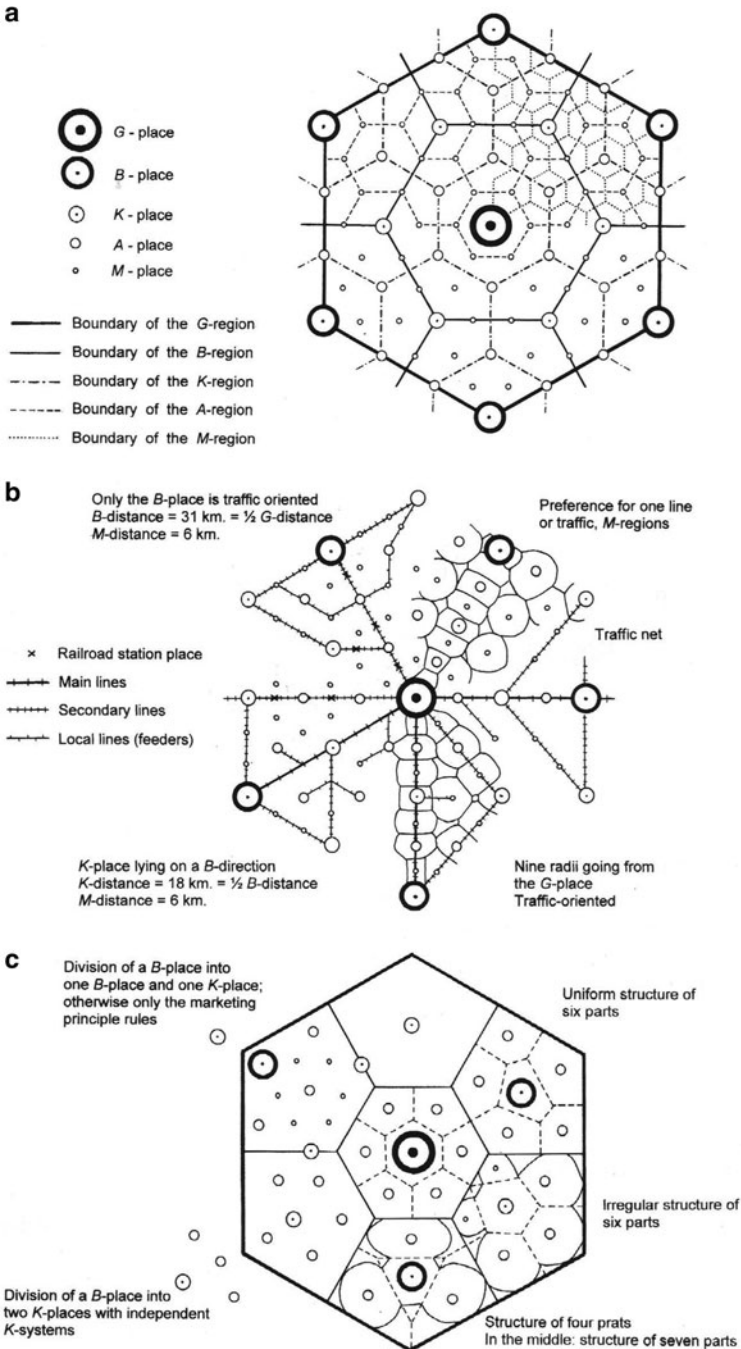


Fig. 2.6 Christaller's systems of central places according to the three locational principles. (a) The marketing regions in a system of central places. (b) A system of central places developed according to the traffic principle. (c) A system of central places developed according to the separation principle (Source: Christaller 1966, Figs. 2, 4, 6)

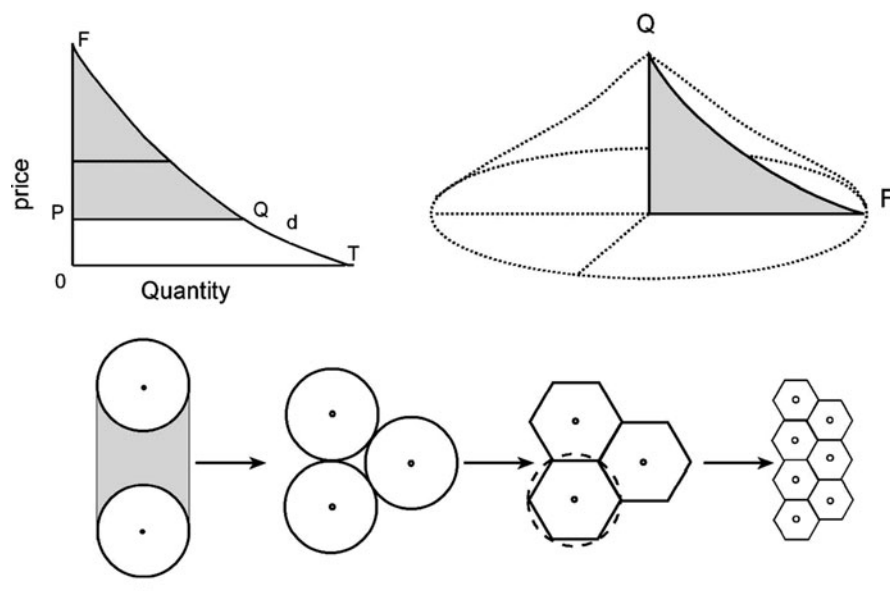


Fig. 2.7 The derivation of Lösch's system of central places. *Top*: The derivation of a spatial demand cone with its market area (*right*) out of an "ordinary" demand curve (*left*). In the words of Lösch (1945, pp 105–6 and Figs. 20–22): "Let d (*top, left*) be an individual demand curve for beer. If OP is the price at the brewery, ... those living at P will buy PQ bottles.. Further away the price will ... be higher ... and the demand ... smaller. ... at F ... no beer can be sold. Thus PF will be the extreme sale radius for beer, and the total sales ... will be equal to the volume of the cone that would result from rotating the triangle PQF on PQ as an axis" (*top, right*). *Bottom*: Development of market areas from the large circle to the final small hexagon. The above deduction (*top*) "would be relevant if economic regions were circular. But they are not. ... because all the corners between the circles would not yet have been fully turned to account ... the corners can be utilized by pressing the circles together until a honeycomb results. As a consequence ... the total demand curve will be shifted downward. But the hexagon can be made smaller, until the total demand curve ... touches the supply curve. Then the market is full." (Lösch 1945, pp 109–110, fig. 23)

Lösch's theory is more ambitious and complex than Christaller's. While the latter's aim was confined to *tertiary activities*, that is to say to services, Lösch's aim was a general theory of location. As a consequence, his urban landscape is more complex, first with respect to the levels of the hierarchy and second, with respect to what he has termed as *city-poor* vs. *city-rich* sectors, that is to say, sectors in his theoretical economic landscape, which because of the spatial distribution of cities in them, are better and/or worse served. The original model of Lösch is shown in Fig. 2.8, whereas Fig. 2.9 is a refinement of Lösch as suggested by Isard (1956).

2.4 Rank-Size Cities

In 1913, German geographer Felix Auerbach published an article in which he demonstrated regularity in the size distribution of cities in several countries (Germany, GB, USA France, Austria, Russia). The basic finding is that the size distribution of cities

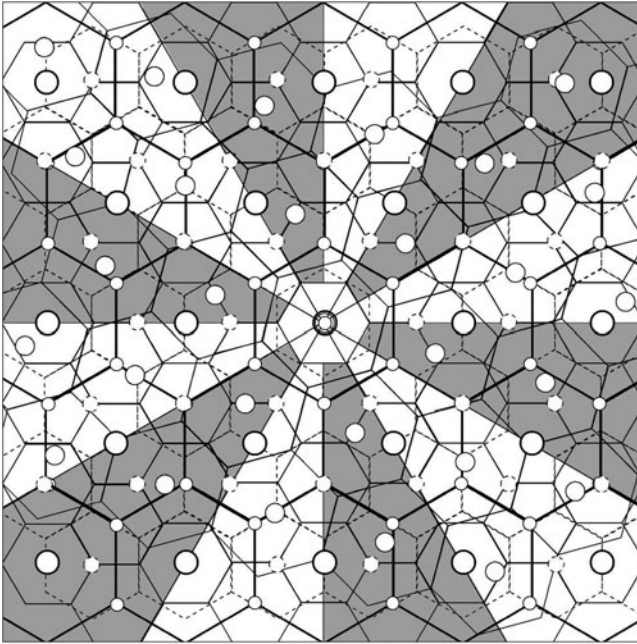


Fig. 2.8 Lösch's derived system of central places with their market areas, divided into city-poor, city-rich sectors (Source: Lösch 1945, Fig. 28)

is hierarchical in the sense that there is one/few big city/cities, more medium-size cities and so on, and finally a relatively large number of the very small cities. About a decade later, the statistician Lotka (1924) introduced the rank-size distribution of city populations on a double logarithmic paper. Pumain (2006, p 190) who surveys the early beginnings of the rank-size rule further mentions other scholars and in particular Gibrat (1936) who suggested the lognormal distribution. Following the above pioneering studies of the rank-size rule, this regularity in the size distribution of cities was found time and again in different countries. A few recent examples are given in Fig. 2.10. Such examples must be taken with caution, however, as a recent empirical study indicates that this is not always the case (Soo 2005). Using new data on 73 countries and two different estimation methods this study concludes that the Zipf's Law is rejected for many of the countries.

The notion of hierarchy enfolded by Auerbach and the other pioneering studies reminds one of Christaller's central place hierarchy and indeed he has not ignored his predecessor: The observation regarding the size distribution of cities and towns, he notes,

... has already led to the statement of a most incredible law. (Christaller 1933/1966, p 59).

And in a footnote he leaves no doubt regarding his view on this "incredible law":

"Auerbach's Law", (Size of place = Size of largest city/Rank of place) is not much more than playing with numbers. (ibid, f.n 19).

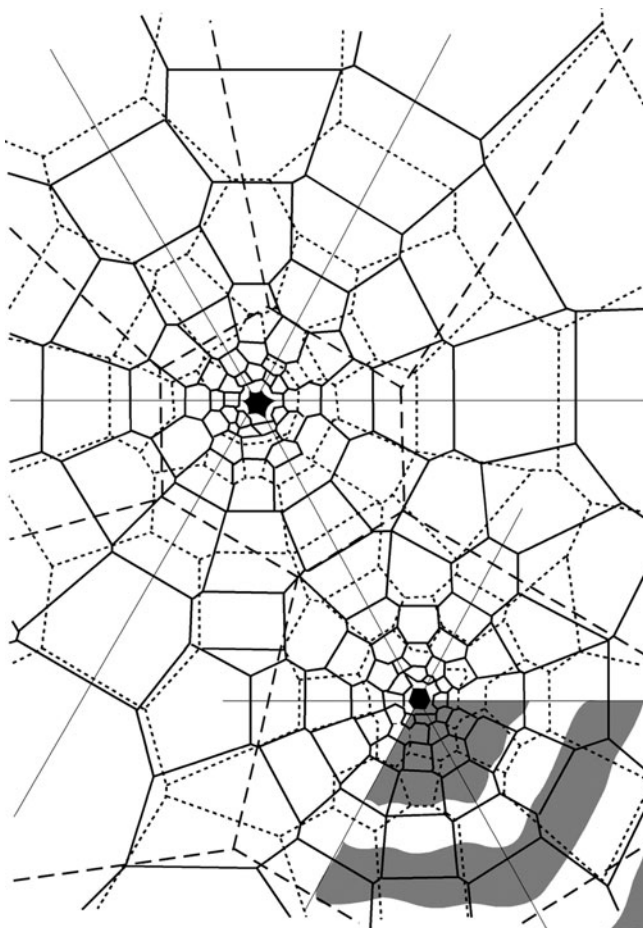


Fig. 2.9 A Lösch system of central places modified by Isard (1956) so as to be consistent with the resulting population distribution

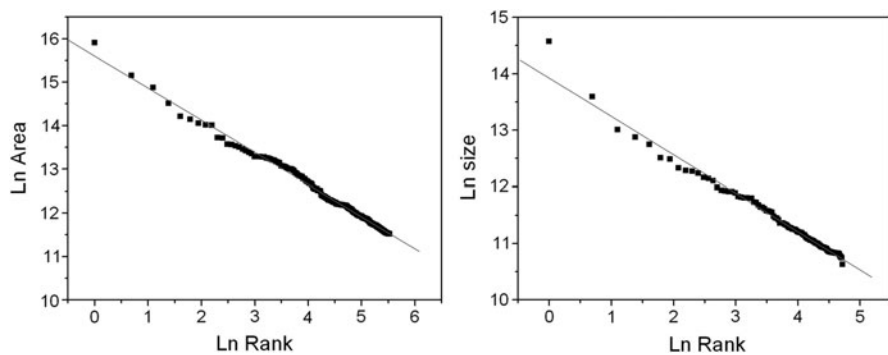


Fig. 2.10 Typical examples of the rank-size rule. The rank-size distribution of cities in the USA (*left*) and in France (*right*)

After dismissing Auerbach's inductive approach to the observed hierarchical regularity of cities he turned to develop his own deductive central place theory as presented above.

But despite of Chistaller's dismissing criticism, Auerbach's idea didn't die. In 1949 Harvard linguist George Kingsley Zipf showed that this rank-size distribution typifies not only cities, but a whole range of phenomena (Zipf 1949) and by so doing he got all the fame so much so that this distribution is commonly called *Zipf's law*. Zipf's work provided a source of inspiration to a long list of subsequent studies on systems of cities (Bourne and Simmons 1978). Once again in the 1970s the idea was criticized for being a statistical observation devoid of sound theoretical basis and once again like the mythical phoenix it re-emerged this time in the context of complexity theories of cities: first as a property of fractal structures in general, then as a central property of fractal cities (Batty and Longely 1994), next in Bak's self-organized criticality cities and as we'll see below, in the new science of networks and in network cities, as a genuine sign for self-organization (Batty 2005). As we shall see in Chap. 4, the two properties that typify rank-size cities as complex self-organization systems are the *scale-free* and *power law* distributions.

2.5 Ecological Cities

Imagine an ecological system with a relatively high population density. The population is composed of several spatially segregated communities, each in its specific territorial niche, the individuals of which are motivated by a simple aim – survival. For this purpose they have to form communities and interact among themselves, as individuals and collectivities, in various forms of symbiosis, competition, domination, invasion, succession, and the like. This ongoing complex interaction, between individuals and communities, is the engine behind the dynamics of our ecological system. The latter might be a small water pool created after the rain, it might be a desert, a jungle, and also, so claim proponents of social and urban ecology, a city.

The ecological image of the city originated out of the Chicago school of *social ecology* and its product *urban ecology*. To be sure, social and urban ecology were not a direct, one to one, application of biological ecology to society and the city. In his seminal book *The City*, Park (1925) builds on top of the *biotic level* that describes the city in universal terms of symbiosis, competition, invasion etc., a *cultural level* that describes the city in unique human terms of social and moral norms, politics and religion. In a paper on “Urbanism as a way of life”, his student and follower L. Wirth (1938) has further elaborated Park's view. He has, first, described society in terms of three orders: the ecological-biotic and on top, the cultural order and the political order. Then, from this general social order, he has delineated the urban form on the basis of three ecological principles of *size*, *density* and *heterogeneity*.

As in biological ecology, where morphological analyses provide the basis to theorize about underlining mechanisms, here too, the formulation of general

Fig. 2.11 Burgess' concentric zone model: (1) central business district, (2) zone in transition, (3) zone of working men's homes, (4) residential zone, (5) commuters' zone

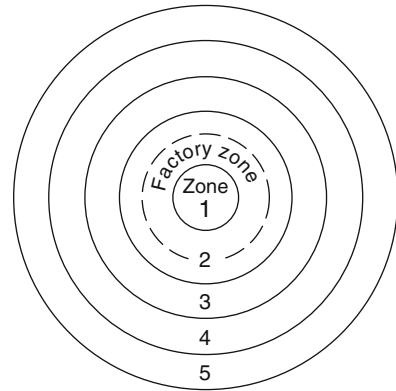
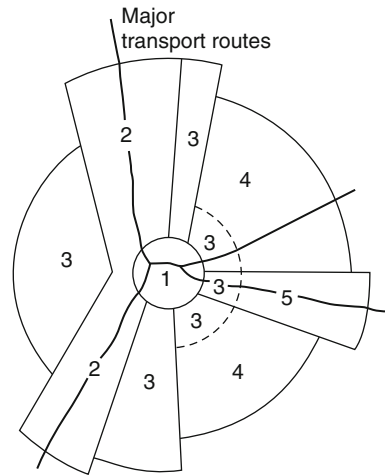


Fig. 2.12 Hoyt's sectoral model: (1) central business district, (2) wholesale and light manufacturing, (3) low-class residential, (4) medium-class residential, (5) high-class residential



principles of urban ecology was associated with several detailed studies of *urban morphology*. The first and probably most influential ecological image/model was put forward by Burgess (1927) who, on the basis of his empirical studies in Chicago, has described the city as an entity that expands radially from its center and in the process forms a series of concentric zones (Fig. 2.11): a CBD zone, surrounded by a zone of transition characterized by high residential and business turnover, a working class zone, a middle-class zone and an outer zone of suburban population-commuters.

Burgess' model was followed by Hoyt (1939) who, on the basis of empirical studies on rent gradients in American cities, suggested a sectoral morphology of the city. In the latter, relatively homogeneous residential and nonresidential areas grow outward from the city center probably along transportation routes, and in the process produce a sectoral pattern as in Fig. 2.12. Burgess and Hoyt's models were integrated by Mann (Fig. 2.13) and at a later stage by Ullman and Harris (1945) in

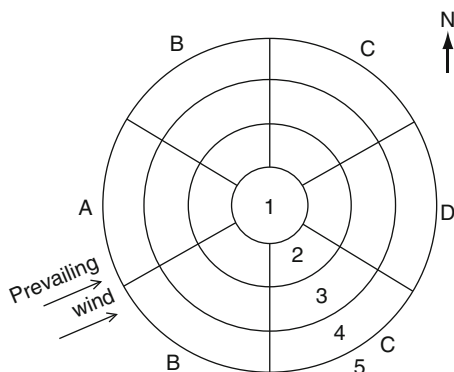
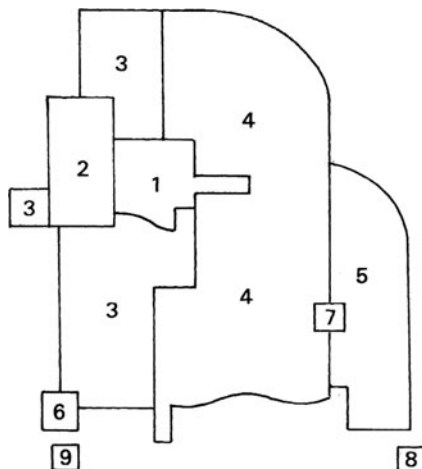


Fig. 2.13 Mann's model of urban structure: (1) central business district, (2) transitional zone, (3) zone of small terrace houses in sector C and D; large bye-law housing in sector B, large old houses in sector A, (4) post-1918 residential area, with post-1945 development mainly on the periphery, (5) commuting distance 'dormitory' towns, (A) middle-class sector, (B) lower-middle class sector, (C) working-class sector (and main council estates), (D) industry and lowest working-class sector

Fig. 2.14 Ullman and Harris's multiple nuclei model: (1) central business district, (2) wholesale light manufacturing, (3) low-class residential, (4) medium-class residential, (5) high-class residential, (6) heavy manufacturing, (7) outlying business district, (8) residential district, (9) residential suburb



their *multiple nuclei model* in which urban growth starts not in one, but in several nuclei thus producing the morphology presented in Fig. 2.14.

The whole of the ecological approach is strongly linked to Chicago. Not only to the Chicago School, but to the very metropolitan field of Chicago which has become the ideal type (in Max Weber's sense) of the city of the fifties and sixties: Its land use rings, spatially segregated ethnic groups, rent-bid curves, and distance decaying population densities appeared in most textbooks (e.g., Fig. 2.15, which is taken from Haggett et al. 1972) and were forced on almost every student of urbanism, planning and social geography. And when a certain instance of urbanism did not conform to the ideal type, as in the case of so many "third world" cites,

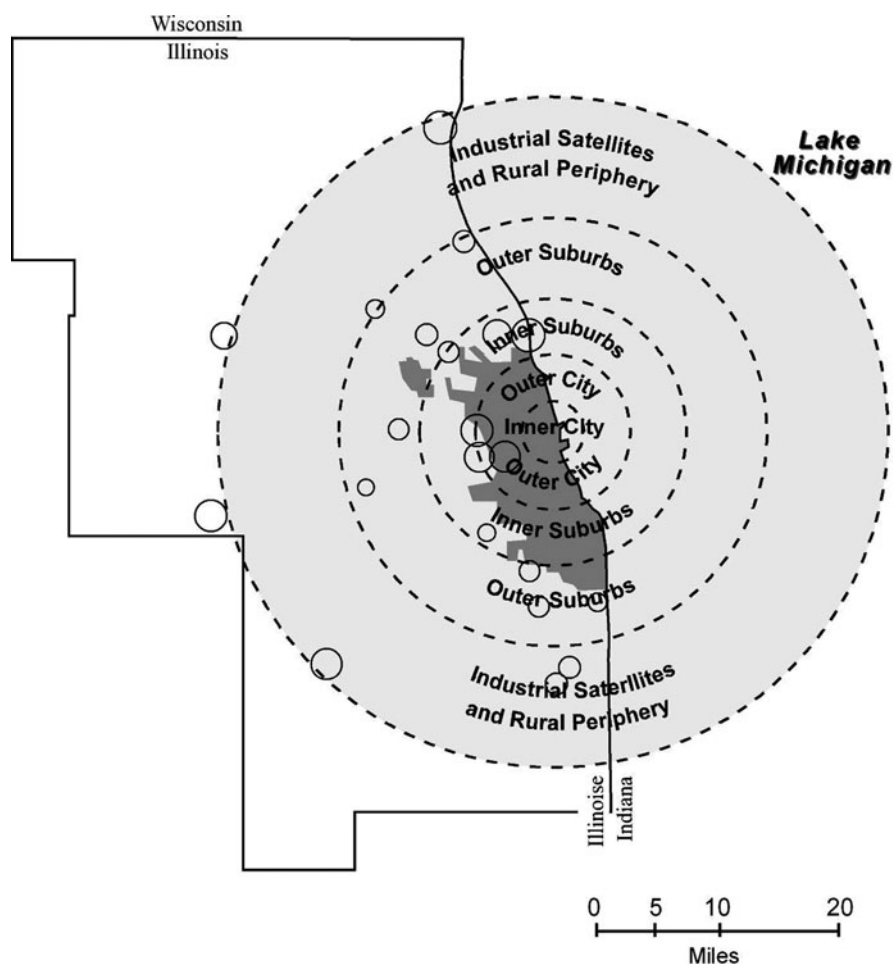


Fig. 2.15 Regional differentiation of Chicago as presented in several geographical textbooks (see, for example, Haggett's (1972, p 263) textbook *Geography: A Modern Synthesis*)

it was treated as exceptional, needing special explanatory maneuvers. The fact that the majority of world population lives in exceptional cities whose structure and nature depart from Chicago never mattered much.

2.6 The Eco-City

It is hard not to see the morphological similarity between the **ecological** cities just described and the **economic** cities of Thünen, Christaller, Lösch and the others discussed above. The ecological city of Burgess is almost identical in its form to the

Thünen-type concentric economic cities – a similarity that was noted by many. To this I would add that Lösch's city-rich/city-poor sectors are not very different from Hoyt's sectors, especially in light of our comment above that Christaller's and Lösch's central place theories were applied to the study of the internal structure of cities.

But the two eco-cities are not only similar visually and morphologically, but also with respect to their underlying mechanism. For both, reality is an arena where plants, animals, individuals and collectivities, compete and fight for survival, and in a similar way, for both the city is the arena for the urban process – the process by which people as individuals and collectivities compete over the urban land(use), either by means of an interplay of spatio-economic rbc's, or by means of ecological invasion and succession processes identified by means of Chicago-type factorial ecologies (Berry and Horton 1970).

These similarities between the two types of "eco-": the economic and the ecological, are hardly surprising in light of the symbiotic relations that characterized the origin of the theory of economics and the theory of evolution when they first emerged in the first half of the 19th century. In his *Science, Ideology and World View*, Greene (1981) follows in some detail the way several ideas about 'free', 'natural', competition and 'survival of the fittest', among individuals and collectivities, first appeared in liberal political economy and social philosophy in the writing of figures such as Malthus, Adam Smith and Herbert Spencer, and only at a later stage have inspired Darwin. The impact of Darwin's biological *Origin of Species* was so strong, however, that it pushed to the shade its early historical origins in the human domain.

Despite the apparent similarity and links between the two eco-cities – the ecological and the economic – throughout most of the 20th century the two research domains were kept distinct from each other with no explicit connection. As I'll argue below (Chaps. 4 and 5), the appearance of complexity theories as theories of complex adaptive systems and their application to cities, paved the way for a more general urban theory that explicitly links the ecological and economic interpretation of cities.

2.7 Gravity Cities

Sir Isaac Newton's law of universal gravitation from 1687 states that two bodies in the universe attract each other in proportion to the product of their masses and inversely as the square of their distance. In direct analogy to Newton's law, several social scientists in domains such as economics, geography, demography and sociology (e.g., Stewart 1948; Isard 1956; Hansen 1959) suggested that two countries, regions, cities, or districts in a city, interact with each other in proportion to the product of their masses and inversely according to some function of the distance which separates them, that is:

$$I_{ij} = kM_iM_j/f(d_{ij})$$

When interaction (I_{ij}) between two locations i and j might refer to the flow of immigrants, goods, traffic, telephone calls, etc.; M_i , M_j masses of cities i and j to population, size of shopping centers; whereas d_{ij} might refer to geographical distance, economic distance (travel cost), social distance and so on, while k is a normalizing constant. An interesting application of the gravitation/interaction logic is Reilly's (1929/1931) *Law of retail gravitation* that attempts to determine the boundaries between different markets or cities in the following way:

$$BP = Da, b/1 + \sqrt{P_a/P_b}$$

where PB is the distance from a given city a to the breaking point, that is to say, to its boundary with adjacent city b ; Da, b is the distance between cities a and b , while P_a and P_b are the population of cities a and b , respectively.

The first interaction/gravity urban models were formulated by a direct analogy to Newton's gravitation, with $f = 1/d^2_{ij}$, then, as a consequence of empirical studies it was realized that the power function is not always 2, and the model was thus generalized to $f = 1/d^a_{ij}$, when power a is determined empirically. Still at a later stage, to a larger extent as a consequence of Wilson's (1970) work on *Entropy in Urban and Regional Modeling*, the model took the form

$$I_{ij} = A_i B_j M_i M_j \exp(-bd_{ij})$$

where A_i and B_j are balancing factors, interpreted also as *accessibility* and *potential* terms. These two terms are interesting as they allow one to envision the city, on the one hand, as an accessibility surface, describing the accessibility of the inhabitants to the city's spatial distribution of goods and services, on the other, as a potential surface, describing the population potential of the city (i.e. spatial demand) to various commercial or service centers of the city. Figure 2.16 is a typical example.

The family of gravity/interaction models is probably the most prominent form of "physicalism" in the study of cities and their planning. At a more basic level,

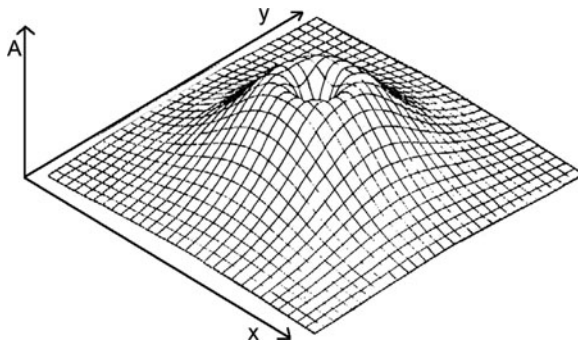


Fig. 2.16 The city of Manchester as an accessibility surface. The city map is decomposed into a cellular space with X and Y coordinates, where A is the level of accessibility. Note that accessibility from the periphery to the city center first increases, then drops toward the very center (due to traffic congestion) (Source: Angel and Hyman 1972)

however, physicalism is but one aspect of the Newtonian-mechanistic world view which forms the foundations for all positivist sciences (Portugali 1985).

The family of gravity/interaction models is the most prominent form of “physicalism” but not the only one. As discussed by Ollson (1975), and exemplified in Figs. 2.2 and 2.5, $\exp(-bd_{ij})$, the negative exponential distance term, is at the roots of the economic cities of location theory just described, as well as of simulation models such as Hägerstrand’s (1967) innovation diffusion (below) and Morrill’s (1965) ethnic segregation dynamics. Hägerstrand’s contribution is discussed next.

2.8 Spatial Diffusion and the City

If the gravity model measures the intensity of the interaction between locations (neighborhoods, shopping centers, or cities), then the theory of spatial diffusion studies the outcome of interaction: the spatial diffusion of cultural traits, of economic innovations, of diseases such as AIDS and SARS, of riots, of the human race, of agriculture (Fig. 2.17) and of cities (Fig. 2.18).

The notion *diffusion* (the full term being *Molecular diffusion*) originally refers to the process by which molecules spread from an area of high concentration



Fig. 2.17 The diffusion of agriculture from its core of origin in the Middle East westward (The numbers indicate years before present)



Fig. 2.18 The diffusion of cities and urbanism from the urban core in the Middle East westward

to area(s) of low concentration. The process is of fundamental importance in disciplines such as physics and chemistry, however, similarly to gravitation it was applied by means of analogy to the human domain in relation to the diffusion of phenomena mentioned above.

While the usage of the notion of diffusion in the human context goes back to the beginnings of the 20th century, the formal theory of innovation diffusion is due to the work of a single person – the Swedish geographer Torsten Hägerstrand (1967) in his book *Innovation Diffusion as a Spatial Process*.

Hägerstrand has used a cellular space as a means to simulate the process (Fig. 2.19). This cellular space is, in fact, Hägerstrand’s version of the “classical” uniform plain of most location theories. The process starts when a certain innovation is introduced at time t_0 at a certain cell of the cellular space (Fig. 2.19 left). This cell becomes the core of the innovation. As a consequence, a *mean information field* (MIF) emerges around the core (Fig. 2.19 center). The MIF is a field of probabilities that indicates the probability of cells (or rather of agents living in the cells) to adopt the innovation. Two processes are crucial in determining these probabilities: one is spatial and the other temporal. The spatial process is the “classical” distance decay function according to which the probability to adopt an innovation at a certain cell is inversely proportional to its distance from the core(s). The temporal process

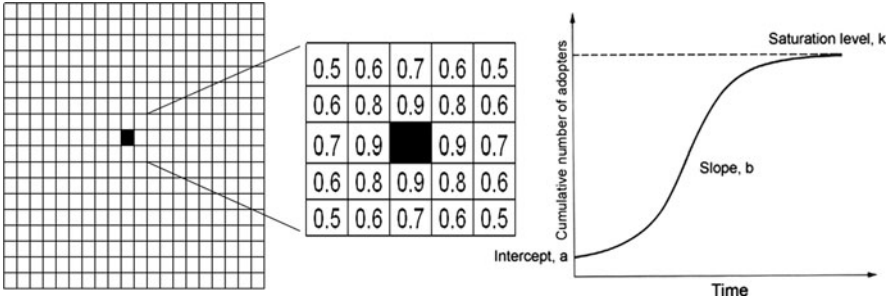


Fig. 2.19 *Left:* An innovation is introduced at time t_0 at a certain cell of the cellular space, simulating a geographical space (e.g., a city, a region) where the ordinate and abscissa are its geographical coordinates. *Center:* A mean information field (MIF) emerges around this cell. *Right:* The temporal build-up in the number of adopters in the cellular space follows the logistic curve

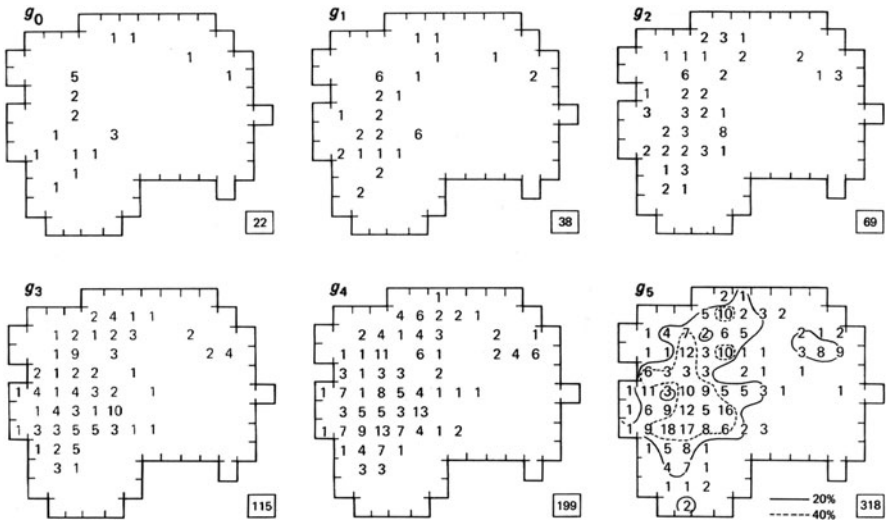


Fig. 2.20 The evolving pattern of adopters of an agricultural innovation as simulated by Hägerstrand (1967, p 23). The numbers in the squares indicate the total number of adopters in the corresponding map

followed empirical observations that the time evolution of the adoption process takes the S-shape form of the logistic curve, namely, at the beginning very few adopt the innovation and the process is slow, then when the innovation becomes popular the number of adopters is growing exponentially and finally the process levels off again (Fig. 2.19 right). Fig. 2.20 shows the evolving pattern of adopters of an agricultural innovation as simulated by Hägerstrand (1967, p 23).

While Hägerstrand's theory was not formulated as an explicit urban theory, it is nevertheless related to cities and to the first science of cities in several ways. Firstly, Hägerstrand's theory of spatial diffusion was used by several writers as means to

simulate diffusion of cities and urban society from their cores of origin in the Near East and East Asia to other parts of the world (Fig. 2.18 above). Similarly to other grand innovations and revolutions in human evolution – the domestication of plants and animals that gave rise to agriculture, for instance – urban society started at one or a few cores (and this is a matter of controversy) from which it then diffused in space and time, very much in line with Hägerstrand's theory.

Secondly, Hägerstrand and even more so subsequent researchers of the spatial diffusion phenomenon studied the way the morphology of the landscape affects the spatial diffusion process. One example is barriers and corridors (Fig. 2.21), while another is what Haggett, Cliff, and Frey (1977) call *central place diffusion*. By the latter they refer to “diffusion down the central place hierarchy” (ibid, p 240). That is, that in many cases the process starts at the largest city of the urban hierarchy, from which it then diffuses to other large cities, then to the next level cities in the hierarchy, then to lower level cities and so on. In this kind of process it is possible that an innovation at New York City, for instance, will be introduced in London and Paris before its introduction to cities and towns in the geographical proximity of New York.

Thirdly, methodologically, Hägerstrand's spatial diffusion theory and model added three innovative elements to the first science of cities: One is a stochastic view and approach to spatial processes and by implication to the dynamics of cities. This was an important innovation as all urban models described above were essentially deterministic in their structure. Two, is the use of simulation models as a theoretical device and as means for empirical analysis. Three, Hägerstrand has added *time* as an explicit parameter in the spatial process; all location theories, as we've seen above, ignore the role of time. These methodological elements, as we'll see below, come close to the methodologies of the CTC approaches to cities and as such form a natural link between these two domains of study (Portugali 1993, Chap. 4, Figs. 4.5–4.8).

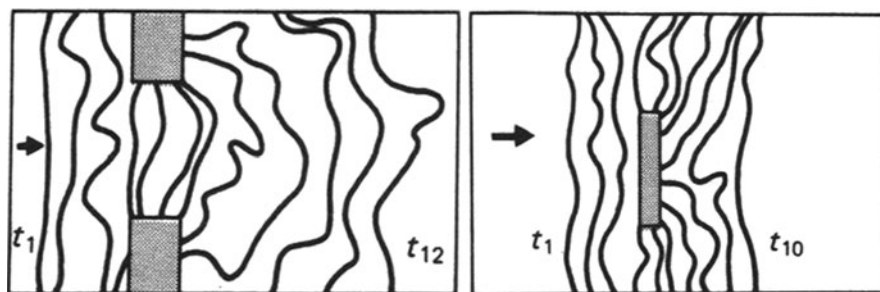


Fig. 2.21 Diffusion with barriers. Diffusion waves passing through opening in a bar barrier (*left*), and round a bar barrier (*right*). X and y are the geographical coordinates of this imaginary space, the arrows indicate the direction of the innovation wave, while t their time at the beginning of the process (t_1) and after the 10th and 12th time units (t_{10} , t_{12}) (after Haggett et al. 1977, Fig. 7.7)

2.9 Cities as Simple Systems

Complexity theory is a theory about systems that are complex in several respects: First, they are open to their environment and exchange with it information and material. Second, their parts are extremely numerous and are linked by a complex network with feedback and feed-forward loops. Due to their complexity there is no way to establish causal relations between the parts of such systems and thus to predict their behavior. Such systems typically exhibit phenomena of chaos, bifurcations, abrupt changes, phase transition, fractal structure and the like. The brain is often described as a typical complex system and cities, too.

None of these properties typify the cities we've described above – on the contrary: the number of their parts is relatively small, they are connected (or rather assumed to be connected) by well-defined rules and causal relations and as such these cities are assumed to be fully predictable; and when in practice this is not the case, the assumed reason is lack of sufficient data. And if the brain can be regarded a typical example of a complex system, then the machine is the metaphor for the cities of location theory.

Two bodies of urban theories suggest that the view of the cities as simple mechanistic systems is misleading and misses the very essence of cities: One such body derives its inspiration from social theory and philosophy, while the other from complexity theories; the first constitutes what we've termed above as the second science of cities, while the second, as we shall see below, has the potential to link the two cultures of cities. The next two chapters elaborate on these two different images of cities – Chap. 3 on the second culture of cities, while Chap. 4 on complexity theories of cities or in short on CTC.



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