Chapter 20
Central Places: The Theories of von Thünen, Christaller, and Lösch

Kathrin Fischer

20.1 Introduction

The question of why economic activities are concentrated in certain places and not in others, why so-called "central places" exist at which an agglomeration of people and trade takes place, and where these central places are to be found, has long been a focus of spatial economists. In the nineteenth and twentieth centuries, three German scientists concentrated on that area, and the results of their research became famous and influential in Germany and all over the world. The three scholars in question are: Johann Heinrich von Thünen ("Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie," Teil I, 1826), Walter Christaller ("Die zentralen Orte in Süddeutschland," 1933) and August Lösch ("Die räumliche Ordnung der Wirtschaft," 1940). Von Thünen was the first to develop a theory of land use, and was praised as "one of the patron saints of econometrics" by Schumpeter (1955). Christaller founded the Theory of Central Places which, in the 1950s, was the only theory "concerning systems of cities that was at all well developed" (Berry 1964) and, especially in the 1960s and 1970s, became the major concept to be applied in regional planning in Germany. Lösch, who is described as an "extraordinary personality" by Stolper in the foreword to Lösch's book, developed the first general equilibrium concept regarding the system of locations of economic activities that had ever been presented.

The three scholars worked in diverse areas: von Thünen concentrated on agricultural land use, and proposed a location theory for agricultural products. Christaller derived a concept to explain the locations, the sizes, and the interrelation of urban settlements. Lösch refined and generalized the resulting theory of central places to a concept on the "nature of economic regions." Although their work is differently

K. Fischer (✉)
Institute for Operations Research and Information Systems (ORIS),
Hamburg University of Technology, Schwarzenbergstr. 95, 21073 Hamburg, Germany
e-mail: kathrin.fischer@tu-harburg.de

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focused, the three researchers have an important aspect in common: in each case, an economic region is defined by the major center which is at its core. The major center has some "sphere of influence" surrounding it, and this sphere of influence economically depends upon the center.

In this paper, the major aspects of von Thünen's, Christaller's, and Lösch's theories are presented, and their interrelations as well as their impact on further developments in the field are analyzed. Moreover, some of the most important subsequent work is discussed, underlining the importance of the fundamental contributions of these three authors for spatial studies and location theory.

20.2 Classical Theories on Central Places

This chapter discusses the theories developed by von Thünen, Christaller and Lösch and the most important results regarding central places. The presentation of each of the theories is followed by a short discussion of its limitations, variations and of possible extensions.

20.2.1 Johann Heinrich von Thünen's Ring Theory

Johann Heinrich von Thünen (1783–1850) was a landowner and farmer who was interested in the mechanisms that lead to the different uses of land in different areas, in different systems of cultivation, and also in the factors that influence the fertility of the soil and the prices of the produce gained from the land. To develop explanations for the phenomena he observed on his own estate, he took an analytical approach leading to a *partial equilibrium model*.

20.2.1.1 Assumptions and Development of the Theory

In developing his approach, von Thünen (1921) considers an "isolated state" (hence the title of his work), in which there is a central city and which is surrounded by wilderness. The surface of the land is assumed to be flat and homogenous without mountains or rivers, and the soil is assumed to have the same constant *a priori* quality everywhere, leading to a standard yield. Farmers are assumed to transport their products directly to the city which is the only place of consumption. Furthermore, each farmer is assumed to behave as a *homo oeconomicus* with the goal of maximizing his profit.

Based on these assumptions, von Thünen wants to determine to which use the land should be put (the "optimal land use"), depending on the distance to the town, which has a crucial impact on the cost of transportation, and under the condition that the demand of the town has to be fulfilled ("supply model"). Early in his paper and without much preceding analysis, he observes that the differences in transportation

cost, resulting from different weights and volumes of products, will lead to a *ring structure* around the central city, where the different rings grow different products. From this seminal insight he develops his model of the "Thünen rings" for agricultural activity which has been praised as the "world's first economic model" by Hall in the introduction to von Thünen's book (1966).

A major part of the first section of von Thünen's book is devoted to an analysis of the farm price of grain. On the one hand, this price—or better: what the grain is worth at a certain distance from town—is determined by the transportation cost. If the price in the central town is known, the prices in different places around the city will amount to the difference of this price and the transportation cost. Therefore, prices will decrease with increasing distance from town, and there will be a certain limit beyond which it is not profitable to produce any grain at all. This defines the limits of the respective ring. In contrast to the majority of authors, von Thünen does not—at least at first—assume that cost of transportation per unit is proportional to the distance travelled. This is due to the fact that he does take into account the amount of food for the horses that needs to be taken on each trip, and hence the unit costs of transportation are slightly decreasing. However, later on he assumes transportation cost to be proportional to distance, e.g., in the case of butter.

On the other hand, the area on which grain is grown and the fertility of the soil are important factors which influence the yield, and therefore the cost, of grain production. The fertility depends on factors such as the use of manure or the rotation of crops. Hence, while von Thünen assumes a homogenous plane and therefore the same "inherent quality of the soil" in his development of an *intensity theory*, he nevertheless takes into account the effect of different levels of fertility.

The data which von Thünen collected on his own farm lead to the proposition that a less fertile soil which produces less grain should only be used for grain when the price is high, as otherwise no profit will be made, due to the high cost of production. In studying different cultivation systems, he found that the improved system in which seven different crops are rotated is not always better than the three-field system. Which of the systems is better depends on the grain prices, with lower prices supporting the three-field system.

In his analysis, von Thünen also takes production costs into account, which he assumes consist of a money ("town-based") part and of a "farm-based" part, calculated in terms of units of grain. It is one of the important contributions of von Thünen that he studies *all* cost aspects and their impact on the choice of location for the different products. He concludes that the product that leads to the greatest decrease in cost when it is produced close to the market and hence saves the highest amount of cost should be produced there; this is the product which leads to the highest *land rent*. Hence, the *land rent* or so-called "locational rent" is the profit which results from the land itself, after the deduction of all cost and the interest for buildings and other objects apart from the land. This rent is the same as the classical "economic rent," but, as von Thünen points out, it is different from the "land rent" in the sense of Adam Smith who does not deduct the respective interest. The land rent also represents land value, and therefore it equals the maximum amount a farmer would be ready to pay for using the land.

From this, Lösch (1962) concluded that, under the assumption of linear transportation costs, the land rent R for a specific product is determined by relation (20.1).

$$yp = yc + yfm + R \quad \Leftrightarrow \quad R = y(p - c) - fmy, \tag{20.1}$$

with the following parameters an variables:

y: yield per unit of land (in tons of product)
c: production cost per ton of product
p: market price per ton of product
f: freight rate per km and ton
m: distance to market (in km)

Therefore, the returns from a product equal the sum of the production cost (which may vary with the distance from town), the transportation cost and the land rent. In other words, the land rent is a residual, as it equals the difference between the cost resulting from the production and transportation of the product at the "marginal site," which is equal to the product's return, and the costs that have to be incurred at the place currently under consideration. (The "marginal site" is the site furthest from town where the product still has to be produced in order to satisfy the towns demand.) The land rent then results from the advantage that a farm has over the "worst" farm that still supplies the market with the same product (usually a farm with high production or transportation costs), and therefore it is a measure of *marginal productivity*: "Land rent does not spring from capital or labor, but from the fortuitous advantage one farm enjoys over the others in the quality of its soil or location" (von Thünen 1966). It can also be interpreted as an opportunity cost: if, for example, another crop were to replace the growing of grain, it should lead to a lower total cost, *including* the grain's land rent.

Consequently, the limits between the rings in which the varying uses of land take place are defined by the land rent: one ring ends and the next ring begins at the point where, for instance, the land rent for the produce of the first equals the land rent for the produce of the second. This concept of marginal productivity can be illustrated as shown in Fig. 20.1. A similar figure on milk production is provided by Lösch (1962).

Figure 20.1 illustrates the tradeoff between land rent and transportation cost. It shows how the Thünen rings result from differences in the costs of transportation (or production) and in the rent that a farmer who raises a certain crop would be ready to pay at a certain distance from the town (named the "bid-rent" by Alonso 1964). The faster the rent for a certain product diminishes, shown by the steeper respective line in Fig. 20.1, the closer to the town the product must be grown.

The Thünen rings can also be derived analytically as explained by Lösch (1962). Consider two products *I* and *II*, such that product *I* leads to a larger rent R_I than product *II*, which leads to rent R_{II}. Using relation (20.1), we can then write

$$R_I > R_{II} \Leftrightarrow y_I(p_I - c_I) - fmy_I > y_{II}(p_{II} - c_{II}) - fmy_{II} \tag{20.2}$$

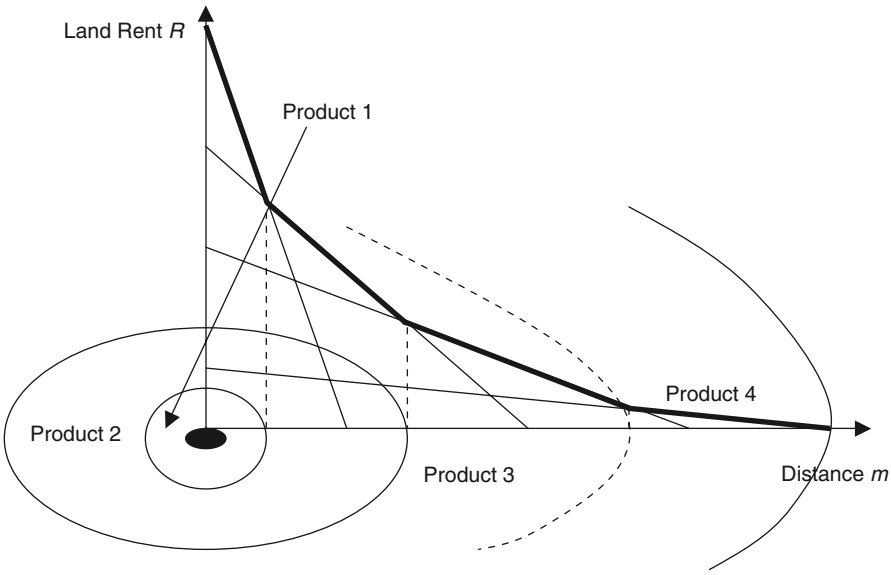

Fig. 20.1 Land rents for different products and the development of von Thünen's rings

At the town, the distance m from the market is 0, and hence this is equivalent to:

$$y_I(p_I - c_I) > y_{II}(p_{II} - c_{II}), \tag{20.2'}$$

which leads to the inequality

$$\frac{y_I(p_I - c_I)}{y_{II}(p_{II} - c_{II})} > 1 \tag{20.3}$$

Therefore, inequality (20.3) must be satisfied, if product *I* can be more profitably produced in the town than product *II*. Analogously, a condition for *II* to be more profitable at the periphery of the area can be derived. The two resulting inequalities are:

$$\frac{y_I}{y_{II}} > \frac{y_I(p_I - c_I)}{y_{II}(p_{II} - c_{II})} > 1 \tag{20.4}$$

If only one of these conditions is true, either crop *I* or crop *II* is grown exclusively as the other cannot be advantageously grown anywhere. If both conditions are fulfilled, we find that if $y_I > y_{II}$, crop *I* will be grown in the inner ring (and note that if $y_{II} > y_I$, the conditions have to be reversed and product *I* will be in the outer ring). Lösch (1954) wrote "the choice of a crop is then a function of distance." While the yield is higher for product *I*, the maximum possible profit per unit, $(p_I - c_I)$, must be smaller, resulting from the first part of condition (20.4). For product *I*, therefore, the profit per unit is absorbed more quickly by the cost of transportation than it is the

case for the other crop. In summary, at some distance from the market the two crops give the same profit, and further out in the periphery, the production of the second product will be advantageous.

20.2.1.2 Von Thünen's Rings

Von Thünen gives a very specific presentation regarding the allocation of the production of different products to the different rings around a central town. This central town is the (only) place of consumption, i.e. the place where the products are sold to the customers, whereas production takes place in the respective rings. According to von Thünen, in the first ring dairy production and intensive farming are to be found, as these products need to be brought to the market very quickly in order for them not to perish; as in von Thünen's time, cooling devices, and especially refrigeration trucks, were unheard of. Obviously, the selling price of the milk has to be so high that it is not attractive for the farmers to put the land to any other use than food production for the cows, with the exception of the production of selected products, such as strawberries, because they would not survive a long transport, and potatoes, because it would be too expensive to transport them over a long distance. A special feature of this ring is that manure is mainly bought from the city. Von Thünen calls this ring the "free cash cropping" ring (in German: "Freie Wirtschaft").

The second ring contains timber and, closer to the town, firewood production. During von Thünen's lifetime, wood was needed for heating and cooking, and as its transportation was difficult due to its weight, it was located close to the place of consumption. In the third ring, crops such as grain are found, because they are not perishable and are much easier to transport than wood. Three different "sub-rings" are defined by the different types of crop rotation: an inner ring, in which the crop alternation system is used, a middle ring with the improved system, and an outer ring with a three-field system.

The fourth (or sixth, if we count the three sub-rings mentioned above separately) and final ring should be devoted to animal farming, including, for example, the production of butter. Von Thünen concludes that butter production should take place at about 30 miles from the town, as it is not worthwhile to produce it at a shorter or longer distance. Closer to the city (except for the "Freie Wirtschaft" ring), the land rent for stock farming is negative and no stock farming will take place there, because close to the town the cost of production steeply increases and overcompensates the decrease in transportation cost. This is due to the fact that crops such as rye are less expensive at larger distances to the town due to the lower land rent, and therefore stock farming, which has a higher production but lower transportation cost than rye (due at least partly to the *consumption* of rye by those working in stock farming), can be done more efficiently further away from the town.

Stock fattening can commence far away from town but has to be finished close to it, as the animals lose too much weight on their way to the town if they have to walk long distances. Also, young cattle can be raised at the outer ring. It should be noted that "industrial" crops which extract a lot of fertility from the ground (e.g.,

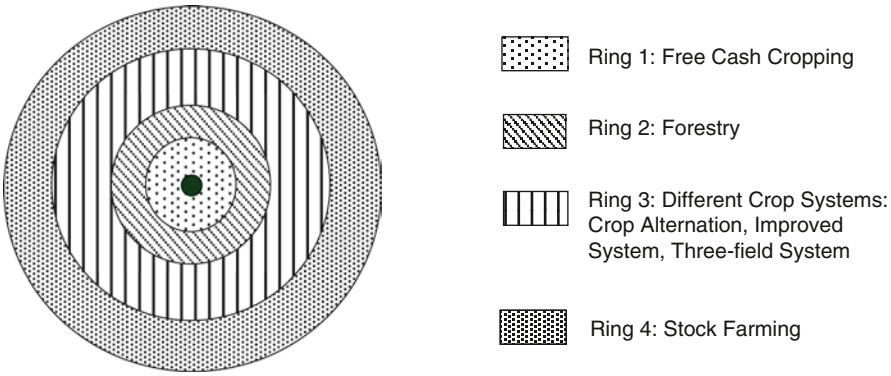

Fig. 20.2 The von Thünen rings in overview

oilseeds, such as rapeseed, tobacco, and flax), are to be found in this outmost ring, as are sheep farming and the production of wool. At about 50 miles from the town, all farming activity ends, as the land rent is too low to support it. Overall, there is a tendency of rising intensity towards town, but there are exceptions like forestry (ring 2). The concept of the rings is illustrated in Fig. 20.2.

Assuming identical costs and/or yields, von Thünen states some general rules regarding the location of different agricultural products:

(a) The higher the production cost, the farther from the market the product should be produced.
(b) The higher the yields of a product, the closer to the market it should be produced.
(c) The crop extracting the most fertility from the soil should be grown farther from the market.

While (b) agrees with the result derived by the analytic procedure, result (a) is somewhat less convincing. Von Thünen states that the lighter or more expensive good is produced farther away, as freight is not so important for such goods, whereas Lösch (1962) subsequently argues that there are cases where it makes sense to produce the cheaper good at the periphery. Moreover, in contrast to von Thünen, Lösch comes to the conclusion that the von Thünen rings are only one possible result. They will form if the economy is dynamic (in the sense that farmers react to changes in the market, such as the introduction of a new crop), whereas in a traditional economy, reversed von Thünen rings are possible as well.

In the second part of his book, von Thünen himself discusses and criticizes his own major assumptions. He states that the soil usually is not of the same quality everywhere, and he drops the assumption of only one central town. The existence of additional smaller towns leads to "sub-centers" which have their own smaller systems of rings. Of course, there are interdependencies between the different rings, as the land rents have to be equal where the borders meet.

Von Thünen also states that towns must be distributed such that their location maximizes national income. According to him, such a pattern will result if all (agri-

cultural) goods are produced at the location which leads to the lowest cost. He has got in mind some kind of spatial equilibrium structure; however, he does not elaborate on the question why and how towns should come into existence at the optimal places and in an optimal pattern.

Moreover, because towns tend to be found near rivers, von Thünen considers the influence of rivers on the regional pattern and concludes that rivers lead to zones of equal transportation costs that stretch along them, as transportation on the rivers can be assumed to be cheaper than transportation on land.

20.2.2 Christaller's Central Place Theory

Walter Christaller (1893–1969) was the first researcher who focused on systems of settlements and the hierarchy of towns, instead of studying them as single units. Nevertheless, von Thünen's work, which mainly deals with a single town, served as one of the major foundations of Christaller's studies.

Christaller's theory of "Central Places" is presented in his book "Die zentralen Orte in Süddeutschland," published in 1933 ("Central Places in Southern Germany," the English translation, appeared in 1966). Christaller is mainly interested in the laws and principles that determine the number, size, and distribution of towns, in order to explain the existing structures he observed in Southern Germany. From his point of view, these could not be explained by geographical aspects, but only through economic theory and, therefore, economic laws.

20.2.2.1 Assumptions and Basic Terms

Christaller's book comprises four parts: a theoretical foundation, the development of a method, a descriptive part on real phenomena, and a final verification of the theory. Observing that centralization around some kind of core or nucleus is one of the basic principles in nature, he states that it is the major purpose of a (market) town to be in the centre of an agricultural area. Being "central" and the notion of centrality are therefore relative notions: Christaller defines *central places* as those settlements which are important for the surrounding area because they provide it with so-called central goods. *Central goods and services* are produced at only a few central places, but are needed and consumed at many different and dispersed places. Examples are medical services, cinemas, schools, and stores. Christaller emphasizes that "centrality" is not so much about the production of goods, but that sales and services are primarily offered at central places due to the capital requirements related to establishing those services.

In order to determine the laws according to which the central places develop, Christaller makes a number of key assumptions: first, the area under study is a flat and homogeneous surface (isotropic plane), on which the population is evenly distributed. Next, all consumers have the same demand regarding the "central goods," and they all have the same income and identical purchasing power. However, those

who live further away from the central place—which in the first instance is assumed to be located in the middle of the respective area—have to use part of their budget (in terms of time and money) in order to travel to the central place, meaning they have to pay transportation costs, and therefore not all of them can spend the same amount on central goods. Finally, transportation costs are assumed to be proportional to distance, and hence customers always prefer the nearest central place (if there is a choice).

Hence, it should be noted that in contrast to von Thünen who assumes the existence of one town—the center of consumption—and dispersed production of (agricultural) goods which have to be transported to the town by the producers (farmers), Christaller builds his approach on the assumption that the consumers have to travel to the central place in order to buy the central goods. Therefore, while in von Thünen's theory a standard transportation cost function can be used to model the impact of transportation on the price of the goods, in Christaller's theory the disutility resulting from travelling plays a role. In other words, "*economic distance*" is the most important factor in determining if a place is indeed central, and this notion relates to the cost of transportation, the time a consumer has to invest in transportation, and the disutility connected with it. The economic distance leads to the *range of a good*, which is the maximum distance people are ready to travel to buy the good, but the willingness to travel to a central place will be different for different individuals, and hence the *economic distance* or range is also an individual measure. Each central place is surrounded by a so-called *sphere of influence*, which is the market area that it serves. The size of this area depends, among other things, on the price of the good and on the transportation cost. It has to be noted, however, that better roads or railways can facilitate transportation of central goods, and therefore reduce cost and "transportation resistance," which leads to a higher consumption of central goods, to an increase of the ranges, and to better developed central places.

With relation to the sphere of influence, Christaller distinguishes between *centers of high and low order*. He assumes that at a center of higher order (such as a place with a university) all the goods and services of lower order (like a school) are on offer as well, but not the other way around. This leads to a *hierarchy* of central places, where the importance of a center is not equal to the number of people living there, but depends on the intensity with which central functions are executed. This, in turn, is related to the number of central goods that are on offer and their ranges.

On the one hand, the range of a central good depends on the distribution of the population and on the order of the central place: the higher the order of the central place (and usually, the larger the place itself), the more different central goods are on offer, making the place more attractive and increasing the range of the goods. On the other hand, the amount of central goods that are consumed and hence the *importance of a central place* depend on the sphere of influence, on the number of inhabitants, and on the population density: the higher the population density, the more central goods will be consumed, and the larger the sphere of influence, the better the central place will be developed.

The characteristics of the goods are important as well: A central good that can easily be substituted will have a lower range than a good which can hardly be sub-

stituted at all. For example, bread can be bought in many stores and hence can be substituted without difficulty, while a special wedding cake has to be ordered at a specialized bakery. Moreover, it matters if the good is available only in limited amounts or if there are no limitations, if the prices are fixed or variable, and if the good is also offered at other places. With respect to the last aspect, Christaller differentiates between the *absolute range* (the distance at which people do not buy the good at all) and the *relative range* (the distance at which they prefer to buy the good from another central place).

These different aspects lead to the individual range of a good, which is an upper limit. There is, however, also a lower limit, the so-called *threshold*, which is the minimum distance from which people have to travel to the central place to buy the good in order to make offering it worthwhile and profitable. Based on range and threshold, the place can be classified as a "higher order place" if both are large, and as a "lower order place" if both are small. If the upper limit is high and the lower is small, the good can be offered in many places, and hence it is a "low order" good.

Christaller concludes that each central place will expand its market area as much as possible, and because the ranges are identical for central places of the same order, these central places have to be spaced regularly. Furthermore, there is a tendency towards more than one central place, as when people have to travel smaller distances, more people can get serviced and total consumption increases. However, those who offer the service or good have to be able to make a living from it, which requires enough customers to support them. Hence, the optimal constellation must be such that the demand of the whole population is satisfied from a minimum number of centers, and this leads to the maximum possible profit for those who offer the good. In this sense, Christaller is aiming at an *equilibrium pattern* of central places. It can be called a supply equilibrium, as it is aimed at serving the whole population.

20.2.2.2 Christaller's System of Central Places

Under the assumption that each customer is always served from the nearest location (an assumption that, to this day, is made by most location analysts, e.g., in competitive location models), Christaller develops a basic spatial pattern which the locations of the central places have to follow in order to serve the whole population with all central goods. The development of this pattern is explained as follows.

First, assuming one central good with a certain range r, and a homogeneous plane with an evenly distributed population, a simple, circular sphere of influence results, as shown in Fig. 20.3.

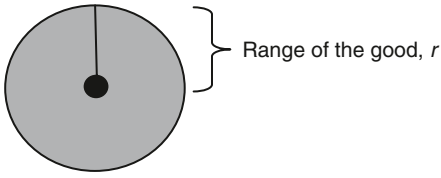

Fig. 20.3 Circular structure of the market area around the central place

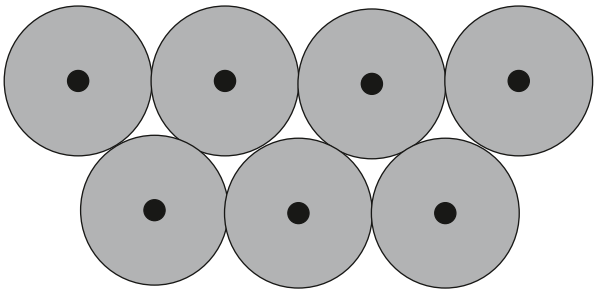

Fig. 20.4 Pattern resulting from many circular market areas

The black dot represents the central place from which all customers within the range of the good, shown by the gray area, can be served. As those people who are not in this area cannot be served from there, additional central places are needed to serve them. The resulting pattern, the so-called hexagonal circle packing, which is the densest packing of circles in the plane (Fejes 1960/1961), is shown in Fig. 20.4.

However, as is obvious from Fig. 20.4, in this pattern there are areas which are not served at all. Hence, to serve all customers, the central places have to be moved a little closer together, such that the spheres of influence overlap. Defining central places for the goods of lower order at those points where the market areas meet leads to a hexagonal pattern of central places and to market areas as illustrated in Fig. 20.5.

As stated above, if the whole population is to be served by a minimal number of central places, these places have to be in a regular pattern. When the central places are arranged in the form of equilateral triangles, as it is the case in Fig. 20.5 (note the dotted lines), the market area for each supplier reaches a maximum and the whole population is served: according to Christaller's objective, this is the optimal spatial structure of central places.

In order to determine the distance between the central places of the lowest order, the length of one of the edges of the basic triangle, ℓ, has to be found. The Pythago-

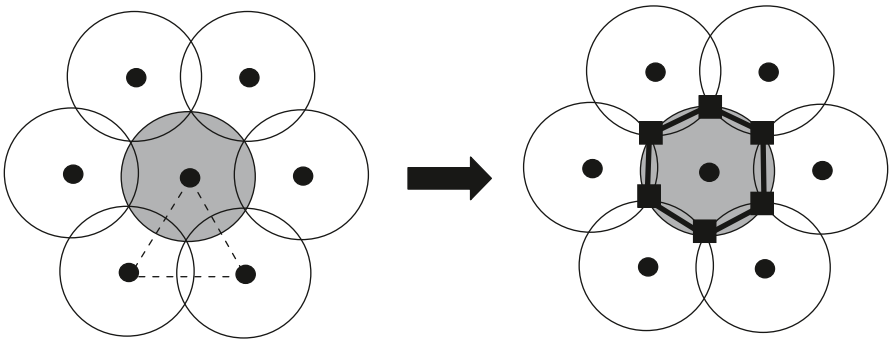

Fig. 20.5 A hexagonal market area

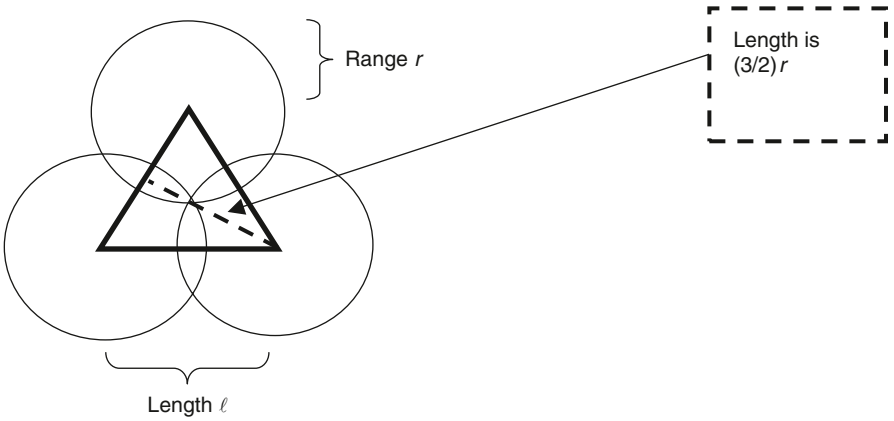

Fig. 20.6 Basic triangle of central places. (Similar to Lang 2002)

ras formula (with r being the range of the lowest order good which is assumed to be known) leads to relation (20.5).

$$\ell^2 = \left(\frac{3}{2}r\right)^2 + \left(\frac{\ell}{2}\right)^2 \Rightarrow \frac{3}{4}\ell^2 = \frac{9}{4}r^2 \Rightarrow \ell^2 = 3r^2 \Rightarrow \ell = r\sqrt{3} \qquad (20.5)$$

Figure 20.6 illustrates relation (20.5) with such a triangle.

The triangular basic shape leads to the maximum possible market areas for the central places and to the hexagonal structure that has been already described above. As there are different central goods of increasing order, a system of hexagons of different sizes results (see Fig. 20.7). The resulting location pattern is called *supply*

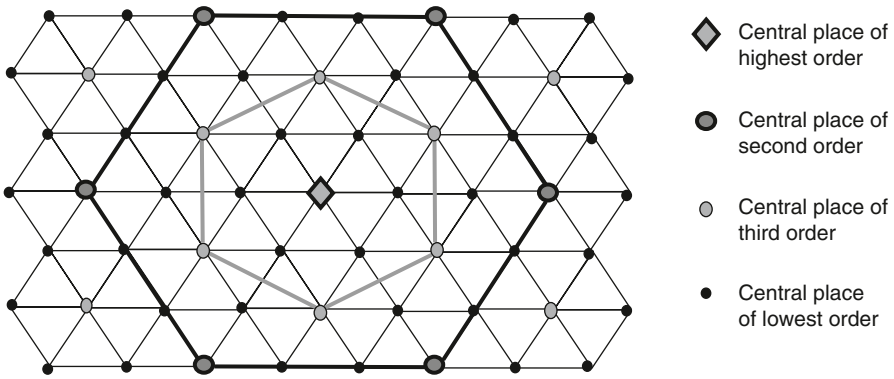

Fig. 20.7 Hierarchical structure of central places

principle, marketing principle or $K=3$ *system* because the market area of a higher order place is three times the size of the market area of the next lower order place. Moreover, three marketplaces are served with higher order goods from a place of higher order, namely the higher order place itself and one third of each of the six surrounding places of lower order. (Note that customers are assumed to patronize the closest location, allowing the demand of the lower order place to be split evenly among the three higher order places to which it has the same distance.)

The smallest central places are only "supportive places" and are to be found in the middle of the triangles shown in Fig. 20.7. The resulting structure of settlements shows certain basic principles: the lower the order, the larger the number of settlements of this order will be, while higher orders will serve larger areas.

Christaller's first main result, therefore, is that there is a *regular pattern of central places* which follows certain laws: there is an important place "in the center" (highest order), with six small places around it (lowest order). Then follows a ring of medium sized places around that and, following another ring of small places, there is a peripheral ring of medium-to-large places (second-highest order). The second result implies the *existence* of those different categories of central places, and, according to Christaller's third result, the *number* of central places of each order increases geometrically, with the lowest number of settlements for the highest order. The numbers of central places will then develop as shown in Table 20.1.

While the smallest central places offer only a few goods—Christaller estimates ten—the next larger places might offer about 40, the next 90, then 180 and 330 goods, and so forth, so the number of goods on offer increases. The importance or level of a central place is directly related to this number of goods.

Christaller's system or principle is *rational*, as it leads to an optimal use of the central places and to the smallest possible loss in the economy; the producers and salesmen make the maximum profit, and all the consumers are served. Of course, in reality there are many obstacles to this optimal pattern; therefore, for example, places of the lowest order can be missing completely. Historical development has a big influence on the existing structure of central places, too, as when one or two big central places already exist, they determine the structure of the smaller places around them. However, governments can help to establish a more efficient structure by setting up their administrative offices in the right places.

It is a special feature of Christaller's approach that he does not develop a structure based on the (existing) traffic conditions, but that he assumes the traffic conditions to result from the system of central places. He argues that the existence of central goods, for the exchange of which people have to travel, leads to the ex-

Table 20.1 Numbers of central places and market areas

Order of place	1st (highest) order	2nd order	3rd order	4th order	5th order
Number of places	1	2	6	18	54
No of market areas	1	3	9	27	81

istence of traffic and the respective infrastructure, but not the other way round. Consequently, traffic structures in the supply system will be dissatisfying because the central places of different orders usually are not to be found on straight lines. If, for example, two central places of the second-highest order (gray with bold black line in Fig. 20.7) are connected, then only two places of the lowest order are to be found on that connection (see bold black lines in Fig. 20.7). The traffic structures can be modified to include more places of different order, but in essence the supply principle does not lead to a good solution of traffic and transportation problems.

Therefore, Christaller also considers the *transportation or communication principle*, which is aimed at the realization of as much transportation as possible, (the maximization of connectivity) at the lowest possible cost (a minimal network length). This leads to a different structure of central places which can be illustrated as shown in Fig. 20.8.

According to the transportation principle, the lower order places are to be found on the edges of the hexagon instead of the corners. Therefore, each higher order place serves a total of four places of the lower order, the place itself and half of each of the six neighboring places, and hence, this principle is also called the $K=4$ *principle*. There is a larger number of central places in this "linear" traffic-oriented system, and hence the "supply principle," which means to serve all customers from the minimal number of central places, does not work here. Moreover, as more central places lead to a higher demand for central goods, demand will be higher and therefore traffic will be more intense when the transportation principle is applied.

A third principle that is discussed by Christaller is the *administrative or political principle*. Here it is necessary to find a unique allocation of some lower order places to a higher order place, such that the respective group of settlements defines an administrative district. In this principle, seven central places—one of higher order and six of lower order—are put together to build a unit, which is why the system is also called the $K=7$ *system*.

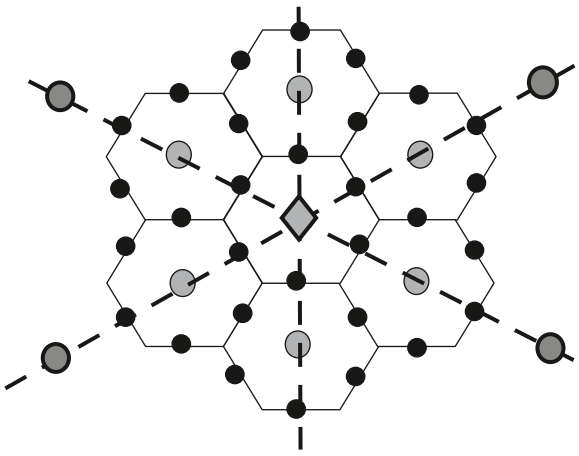

Fig. 20.8 The $K=4$ system or transportation principle

20.2.2.3 Variations and Empirical Implications of Christaller's Theory

After the development of the three principles described above which are of a static nature, Christaller proceeds with introducing dynamic aspects into his theory. He discusses changes in demand resulting from changes in the size of the population, i.e., an increasing (decreasing) number of people, which leads to higher (lower) importance of certain central places, and can even result in new central places coming into existence (or old places disappearing). Changes of prices are also considered, as are changes in the number of central goods that are on supply at certain central places. Christaller points out that the introduction of an additional central good does not only lead to higher sales of the respective good, but also to higher sales of other goods. The major advantages of agglomeration are discussed by Christaller, as are the effects of the land prices (and related rent), which usually will be higher in places of higher order than in places of lower order. He considers this to be an obstacle to too much centralization.

Furthermore, he states that technological progress will lead to cheaper production and transportation, as indeed it did in the last century. A decrease in the cost of transportation leads to more money being available for actually buying the goods. Moreover, people will be able to travel longer distances to buy the goods, thus increasing the range of the goods. Therefore, the goods can be offered in fewer and more distant central places, while still serving all customers. As a result, the larger central places will grow even more while others lose importance, and smaller central places close to a larger one may even disappear altogether. For example, if a new railroad station is built, central place(s) which now can be reached by train will increase in importance, as the "economic distance" to them decreases. Moreover, people will buy different goods at this place which in turn will lead to an increase of the range of the goods offered there, leading again to more agglomeration.

In the second part of his book, Christaller establishes a relationship between his theory of central places and the situation in Southern Germany. He applies his theory to the existing structures to judge which settlements are central and to determine their order. To do this, he first classifies different administrative, cultural, medical, entertainment, and organizational services as well as sales, crafts, and traffic services as of low, medium or high importance. For example, while a police station is of low importance, a Lower Court would be of medium and the Superior Court of major importance. To quantify the importance of a central place, he uses the number of private phone lines that exist in a place. At his time, he found there to be one phone line per 40 inhabitants on average. According to his approach, a central place is of higher importance if it has more than the "expected number" of phone lines, and of lower importance, if it has less.

In his general discussion, Christaller starts from the least important central places (the "supportive" central places) and then works his way up through *M*-places (markets), *A*-places (Amtsgericht, the Lower Court), followed by the *K*-places (Kreisstadt, small district town), the *B*-places (Bezirkshauptort, major district town), the *G*-places (Gaubezirksstadt, Superior Court), the *P*-places (Provinzialhauptort, seat of provincial government), and up to the most important *L*-places (Landeszentrale,

major central city). But in the specific analysis of Southern Germany, he defines the *L*-places which are central for a larger area first, and then works his way down to the smaller places. He calls the central place of highest order "system-building" or "system-defining," as it is the basic element of the system. Around this major place, central places of lower order are located in a regular pattern as illustrated in Fig. 20.7. This might be the reason why it is often argued that Christaller went "top down" in his analysis, while Lösch went "bottom up" (see von Böventer 1963). However, they both start their theoretical development from the smallest settlements while finding the existence of a major central place to be crucial for the resulting overall structures.

The typical distances that Christaller observes in reality are 7–9 km between each two central places of the lowest order (*M*-places), and hence the radius of the sphere of influence is 4–5 km. This is the distance that can be covered by a one-hour walk, and obviously there are many central goods for which the "critical distance" or range is about an hour. The distances between the central places should—according to the supply principle and going from the lowest to the highest level—then obey the following scheme:

$$4 - 4\sqrt{3} - 12 - 12\sqrt{3} - 36 - 36\sqrt{3} - 108 - 108\sqrt{3}, \text{ i.e.,}$$
$$4 - 7 - 12 - 21 - 36 - 62 - 108 - 187.$$

These are the theoretically correct distances. They are not always found in reality, though, and if they are not, there must be an "explanation which is due to special economic, historical or natural circumstances."

In the third part of his work, Christaller studies the five different central places of highest order in Southern Germany, *viz*., Munich, Nuremberg, Stuttgart, Frankfurt and Strassburg, and discusses the urban structures around these central places. He finds that in the case of Munich and Nuremberg, his rational system does seem to work and reality fits the central place system rather well. In the case of Stuttgart, however, the results are not that clear cut. While in most cases the structure follows the supply principle, in other cases it can be better explained by the transportation principle, as is the case for the city of Frankfurt.

In the fourth and last part of his book, Christaller concludes that his three principles indeed are "laws of distribution of central places" that are at work in different areas. He considers the supply principle to be the major distribution principle, and the transportation principle and the administrative principle to be secondary and, therefore, less important.

20.2.3 Lösch's Theory of Economic Regions

In 1940, August Lösch (1906–1945) published his book "Die räumliche Ordnung der Wirtschaft" (the English translation "The Economics of Location" appeared in 1954), in which he refined and generalized Christaller's theory of central places—

but, as he claims, without even knowing Christaller's book beforehand. Similar to Christaller, the focus of Lösch's work is on the interdependencies of locations of production and consumption and on the nature of economic regions (such as the distribution of population and cities), and not on the isolated study of one specific location or location choice.

Among other research, Lösch's book is based on the work of Palander (1935) and Ohlin (1933). He criticizes Weber's partial equilibrium theory, and, following Stolper in his foreword to Lösch's book, Lösch "…was the first to present a full general equilibrium system describing in abstract the interrelationship of all locations." However, in contrast to Christaller, whose aim it is to find a way to supply the whole area with a minimum number of marketplaces—i.e., this is essentially some kind of minimum covering problem as it was later introduced by Toregas et al. (1971)—Lösch concentrates on the effects of competition which lead to the smallest market areas possible. Hence, essentially his objective is to maximize the number of independent economic units and, therefore, of locations.

20.2.3.1 Introduction

In Part I of his book, Lösch discusses previous work in the area (such as the work by von Thünen, discussed in Sect. 20.2.1 of this chapter), and lays the foundation of his own work. Lösch's basic assumption is that each location is chosen such that utility is "as great as possible." For an industrial location, this leads to the "location of the greatest nominal profit." If demand is completely inelastic, as assumed by Weber (1909), this is the point of minimum transportation cost. This point can be determined by different means, especially geometrically by using Weber's isodapanes. These are lines of identical total freight per unit, in which costs for the transportation of raw materials as well as costs for the transportation of the final products are taken into account. Production costs must also be considered, as Lösch points out. (As Isard (1956) demonstrated, the point of minimum transportation costs remains optimal with respect to profit maximization, if the production function coefficients are fixed.)

However, it has to be taken into account that usually demand depends on the price and the location, and that the three aspects are therefore interdependent. In other words, it cannot be assumed that the demand is independent of the location, because the market area depends on the location, and so market area and demand will change with it. Lösch points out that in this situation, isodapanes are of no use at all, and that the only possibility to find the best location is a "trial and error approach."

While his predecessors such as Weber (1909) only concentrate on parts of the system instead of considering the system as a whole, Lösch presents an integrated analysis that is one of his major results, *viz*., the "general equilibrium in space." This general equilibrium results from two forces: the maximization of individual advantages (utility) and the maximization of the number of independent economic units. From these, Lösch develops five conditions which define the equilibrium.

According to condition 1, the location of each individual (be they farmer, entrepreneur, or customer) must be as advantageous as possible, meaning it has to lead to the highest possible profit or utility. Moreover, there are three conditions which make sure that the number of enterprises reaches its maximum. Condition 2 states that there must be so many locations that the entire space is covered. According to condition 3, all abnormal profits must disappear, leaving prices equal to costs. Condition 4 states that all areas of supply, production, and sales must be as small as possible, or more entrepreneurs would come onto the market. Finally, condition 5 implies that "at the boundaries of economic areas it must be a matter of indifference to which of two neighboring locations they belong."

These five conditions and the resulting types of equations define "the size and limits of market areas, the situation of production locations within them and within the entire area, and the f.o.b. prices." The resulting system of equations, however, cannot be solved in general terms. As Stolper in the foreword to Lösch's book puts it, the theory is "too all-inclusive to be applicable." Moreover, in the subsequent discussion, Lösch points out that the best location for the producers does not have to be optimal for the consumers, and that the structures in industrial production which lead to the existence of cities are different from those in agriculture, as the latter are much more dispersed.

20.2.3.2 Lösch's Theory of Economic Regions

Lösch states in the preface to his work that "Parts II and III are the kernel of the whole book". The discussion below will mostly concentrate on Part II which contains Lösch's development of economic regions and relates to Christaller's system of central places. An overview of the content of Part I was already given above in Sect. 20.2.3.1, and a brief overview of the contents of Parts III and IV can be found below, at the end of Sect. 20.2.3.3.

Part II of Lösch's book is dedicated to *economic regions*. In his analysis, Lösch assumes that raw materials are evenly distributed, that the whole area is homogeneous and that there exist only regularly distributed farms. If now any of these farmers starts to produce a good such as beer, this good will be bought by other farmers, but only by those who are not too far away. Hence, it can be assumed that demand decreases with increasing distance, and furthermore that only those who live within the necessary shipping distance ("Versendungsreichweite") will buy the product from the respective supplier at all. (Note that Lösch does not consider the range or the maximum distance people would travel to buy the product. Instead, he only considers the threshold, i.e., the distance that has to be covered to render production worthwhile, as in contrast to Christaller he concentrates on minimum sized market areas).

Due to the homogeneity assumption, Lösch's first approach leads to circular market areas as does Christaller's. But also under Lösch's assumptions, this structure cannot be optimal because parts of the plane are left unused (in contradiction to his conditions 2 and 4). Therefore, the circles have to be reduced to hexagons or

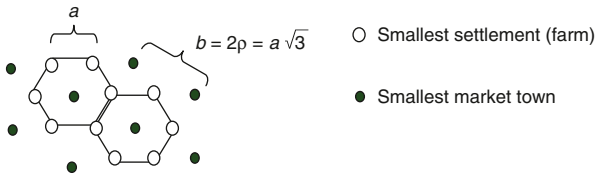

Fig. 20.9 Honeycomb scattering, smallest market areas

honeycombs, which are completely enclosed in the circles and cover a somewhat smaller area. Those hexagons will have the minimal size necessary to support the living of the suppliers, in accordance with condition 4, and will therefore allow for the maximum number of independent enterprises. The size of the hexagons belonging to any specific product can be described by the radius of the inscribed circle, ρ, which depends on the production cost and the demand. If now the smallest settlements (farms) have a distance of *a,* and their areas are regular hexagons, they will be found in a form of "honeycomb scattering" as shown in Fig. 20.9.

The distance between the smallest market towns, *b,* corresponds to the diameter of the circle inscribed in the hexagon, 2ρ (where ρ is expressed in freight costs and *b* is expressed in kilometers). Finally, the furthest distance at which the good must be sold to make its production worthwhile is called *nV*. This corresponds to Christaller's threshold.

The smallest possible value for *nV* is *a* (if we assume production to take place in one of the settlements) and the smallest number of settlements served is three, as in Christaller's model (each market town serves 1/3 of each of the six settlements surrounding it, and it serves itself). The distance between two market towns, *b*, is also the same as in Christaller's model, i.e., $b = a\sqrt{3}$. However, in contrast to Christaller, Lösch argues that there could be products that still have a threshold of $nV = a$, but for which the number of settlements served is not three, but four. This is illustrated in Fig. 20.10.

Each of the small settlements is served from two market places, so a total of four settlements is served from each place that offers goods of order 2, and for such a good, the distance between two places offering it is $b = 2a(= a\sqrt{4})$. In other words, the market area is bigger than in the case of the first good, but the necessary shipping distance remains the same, as only a larger fraction of the same settlements is served. This is a general result: with the increasing order of the goods, the

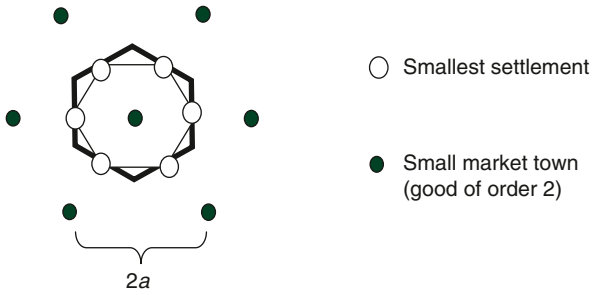

Fig. 20.10 Second smallest market areas

Table 20.2 The ten smallest economic areas

Area #	1	2	3	4	5	6	7	8	9	10
n	3	4	7	9	12	13	16	19	21	25
b	$a\sqrt{3}$	$a\sqrt{4}$	$a\sqrt{7}$	$a\sqrt{9}$	$a\sqrt{12}$	$a\sqrt{13}$	$a\sqrt{16}$	$a\sqrt{19}$	$a\sqrt{21}$	$a\sqrt{25}$
nV	a	a	a	$a\sqrt{3}$	$2a$	$a\sqrt{3}$	$2a$	$2a$	$a\sqrt{7}$	$a\sqrt{7}$

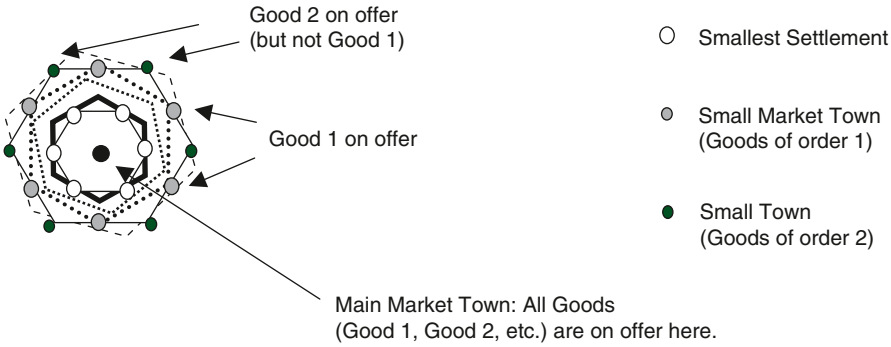

Fig. 20.11 The six smallest market areas

distance b between the market places and the number of places served increases monotonously, whereas the necessary shipping distance nV does not increase in each step, as shown in Table 20.2. The resulting system of hexagonal market areas is presented in Fig. 20.11. Only the first six hexagons are given here (for a similar presentation, see also Lang 2002); the development of the areas of higher order proceeds analogously.

Table 20.2 summarizes the development for the 10 smallest possible economic areas (though they do not all have to exist) and shows the number of settlements served n, the distances between the different centers b, and the necessary shipping distance nV.

A comparison with Christaller's concept shows that the first and the fourth hexagon are the same as in Christaller's model, while the second and third market areas are different. In contrast to Christaller's approach, as can be seen from the development described above and as is illustrated in Fig. 20.12, Lösch does not assume that each good of lower order is on offer in all places of higher order. The only exception is the most central place (the town of the highest order) that offers all the goods. However, the smaller centers specialize in different goods, and they are therefore not in a strict hierarchical order.

According to Lösch, not all possible market areas as they are illustrated above have to actually exist. On the one hand, the resulting market area might be too small to make producing and selling a specific good worthwhile and, on the other hand, the splitting of settlements between central places is not a stable arrangement. In his opinion, it is therefore especially likely for the market areas 3, 6 and 8 to be established, as in these constellations no splitting is necessary.

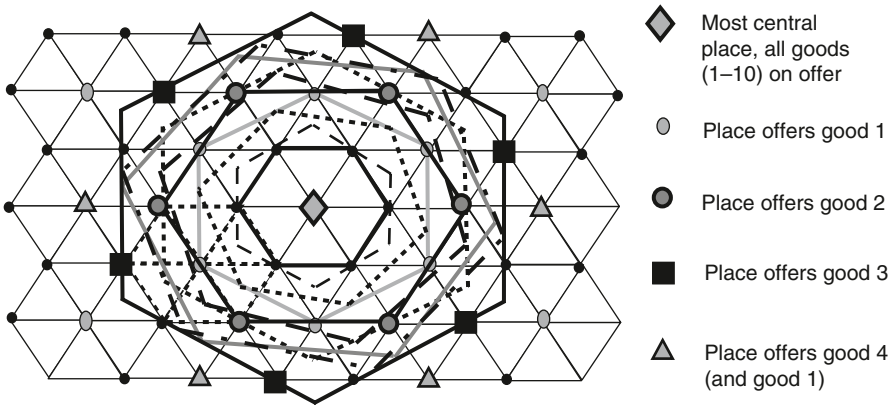

Fig. 20.12 Lösch's system of market areas

As can be seen from Fig. 20.12, there are areas in which more central places are to be found, and places in which there are less of them. Specifically, there is an "empty" ring without central places around the main central place, and there are sections with more central places in some kind of "wheel structure" around the main place. This structure is illustrated in Fig. 20.13.

In the gray spokes, we find places at which more than one good or class of goods is on offer, and these are central places or sites that, as in Christaller's model, are to be found in a regular pattern. The resulting structure for each of the goods (or better: for each of the sizes of market areas, as goods with the same size of market

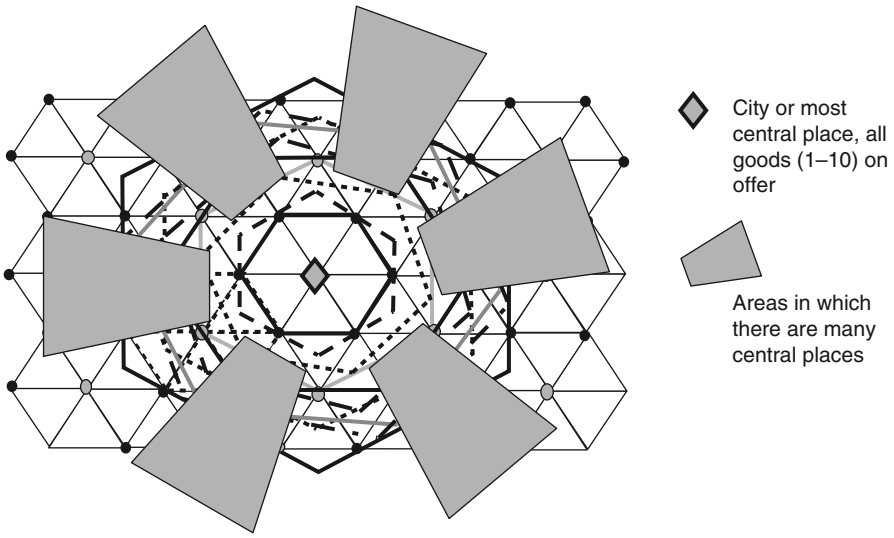

Fig. 20.13 Lösch's system with "city-richer" and "city-poorer" sectors

area will belong to the same class and hence to the same network) is a *honeycomb network*. The market areas of a specific size are to be found adjacent to each other, and the networks of the different sizes cover the whole area. They can be "thrown over our plane at will," but they should have one center in common (the major city), and they should be arranged in such a way that sectors with more and sectors with fewer market towns result. Due to the existence of those "city-richer" and "city-poorer" sectors, there are some bigger and more intensively used traffic lines which mostly leave the central city and lead out from there to the sectors, especially to those that contain more central places. The resulting pattern resembles a cobweb, with the major city as the midpoint. The central city is also the midpoint of a system of rings of economic activity, which is the industrial equivalent to von Thünen's agricultural rings.

Obviously, there will not only be one such system with one most central (major) city, but there will be many of them that are adjacent to each other and that in themselves have a honeycomb structure. In this way, Lösch develops a system of regular economic regions which with their network structure "form…an organic whole". The complete system consists of three different stages: simple market areas, regional networks, and regional systems.

20.2.3.3 Special Cases, Variations and Empirical Results

Lösch examines some typical regional systems, namely those where each area has the size of K regions of the next smaller size. For example, a 3-*system* would contain settlements and areas of the type 1 as the smallest units, then towns of type 4 would be the next larger size (as type 2 and 3 cannot cover three areas of the type 1, they do not exist in a 3-system), followed by type 11 on the next stage which contains three areas of type 4 (again, types 5–10 do not exist), followed by type 30 and type 77. The resulting system has the same structure as developed by Christaller (see his $K=3$ *system* as illustrated in Fig. 20.7). According to Lösch, it has the advantage of having a clearer structure than the full system, but the disadvantage of being less economical, as in this system the areas of many goods are larger than they actually need to be.

Lösch also criticizes Christaller for his claim that the $K=3$ system was most economical. However, this is merely a question of definition, as Christaller assumes the supply principle, and his objective is therefore to supply the whole population from as few places as possible. Obviously, this must lead to a result different from Lösch's who assumes that the number of "independent existences" (suppliers) should be maximized. But nevertheless, Christaller's theory of central places can be viewed as a special case (or better, the three systems can be viewed as three special cases) of Lösch's more generalized theory.

After the presentation of his general theory, Lösch varies his assumptions and studies economic differences (price, product differentiation, the importance of the freight rate) and natural differences (productivity, accessibility, human and political differences) and their impact on his model and its results. It turns out that they

lead to modifications of the theoretical structure in reality, allowing irregular and overlapping market shapes and less regular networks.

Part III of the book is devoted to the specifics of trade. Here, Lösch relates the location problem to other important areas, such as the choice of occupation. Again, he takes a marginal view and develops conditions for an equilibrium in which each individual, e.g., a worker or an entrepreneur, realizes the highest utility possible.

In the fourth and final part of his work, Lösch studies the spatial structure of locations in the United States. For example, among bank branches in Iowa he finds a uniform distribution which agrees with his theoretical results of a regular network structure, and therefore he concludes that "the spatial distribution of most non-agricultural enterprises corresponds very well, after all, with our theoretical model." Moreover, he finds that a "regular distribution of towns throughout the world is extraordinarily common."

20.3 Assessment of the Classical Contributions

As already stated in the introduction, the contributions by von Thünen, Christaller, and Lösch are pioneering and seminal, serving as the basis of many subsequent developments in different fields, including regional science, geography, economic theory, and location theory. Their work is highly interdisciplinary: the three books are named among the "path-breaking books in regional science" (Waldorf 2004) by the members of the Regional Science Association International (RSAI), while at the same time their authors—first and foremost von Thünen, but also Christaller and Lösch—are considered to be very important contributors to economic theory.

20.3.1 Von Thünen's Contribution

Von Thünen's work is the first publication in which—in Part I more implicitly, in Part II explicitly—*marginal analysis* is used to analyze and model an economic problem, namely optimal agricultural land use and the prices resulting from it. Based on the principles of arbitrage and marginal productivity, von Thünen develops his concept of the land rent and an equilibrium concept for land use. As these problems necessarily involve the existence (and location) of central towns as centers of consumption and the question of where to locate which agricultural activities, his contribution is a seminal part of the literature on spatial analysis. At the same time, it is an important contribution to the field of economics: in his "Foundations of Economic Analysis," Samuelson (1983) mentions J.H von Thünen alongside Leon Walras, J.S. Mill, and Adam Smith as one of the most important economists ever. Von Thünen's outstanding work has clearly had a major impact in more than one scientific field, and, as Fujita (2000) points out, his views and insights on modern aspects like agglomeration, are well ahead of his time.

Perhaps the most important contribution of von Thünen is the introduction of transportation costs into economic theory and the extensive analysis of their effects on land use and prices. Von Thünen was among the first to introduce the dimension of space into economic modeling, and in this way he prepared the ground for the many publications in location analysis, regional sciences and spatial economics that followed.

Although von Thünen's model has often been criticized for its simplifying assumptions—the homogenous plane, the single city, the static approach—it still remains one of the most important models of agricultural regional structures, and it is still studied and discussed, applied and modified by economists as well as geographers. This is, as Block and Dupuis (2001) assert, probably due to the important theoretical contribution, but also to its simplicity and to the fact that it is empirically relevant. For example, Rutherford et al. (1967) find a slightly modified ring (actually a belt) structure for agricultural activities in Australia, around and near Sydney.

The major criticism regarding von Thünen's model concerns his assumptions, especially regarding the uniformity of the plane. That he does not take into account the obviously uneven distribution of natural resources, renders his theory less relevant and applicable, at least at first sight. Authors such as von Böventer (1963) point out, though, that many of von Thünen's results remain true, albeit possibly in modified form, if this assumption is dropped.

While von Thünen mainly concentrates on "advantages of site" (i.e. the location), according to Lösch there are different factors which lead to different rings for different products: besides the advantages of site, there are advantages of source (like the quality of the soil) and advantages of scale (where larger amounts lead to lower cost per unit). Lösch also emphasizes that, as in industrial production, there is a tendency to maximize the number of producers, allowing each farm to be only the size necessary to support a family, and to maximize rent. This is an aspect that von Thünen does not study.

Moreover, von Thünen's theory does not explain how cities emerge, as it takes the central city as given. However, in the second part of his work, von Thünen relaxes the assumption of only one major city and even mentions a system of cities of different sizes covering and serving the whole state. Therefore, he can be viewed as a true predecessor for Christaller's central place theory. Finally, it should be noted that von Thünen already elaborates on aspects of industrial location, a theory which was to be formulated in detail no less than 80 years later by Weber (1909).

20.3.2 The Contributions by Christaller and Lösch

Christaller's central place theory is pioneering in the studies of economic regions because it does not concentrate on individual locations in isolation, but instead takes into account the interrelations of different economic activities and their locations. He is the first author to develop a complete system and hierarchy of urban

settlements. It is especially remarkable that the structure of this system is not determined by traffic conditions or other existing structures, but solely by the goods which are on offer at specific places and consumed at many others, the central goods. At the core of his theory is the idea that the goods and their consumption define and shape the economic landscape, an idea which is simultaneously new, simple, and utterly convincing. By taking into account that consumers have only a limited budget and can buy only goods relatively close to their home place, and that suppliers have to be able to sell enough of their product to make its production worthwhile, Christaller develops an equilibrium system of central places and the respective market areas which ensures the cost-minimal provision of all customers with all goods.

Central place theory became fundamental for subsequent developments in different fields of sciences, such as in urban systems research (Coffey 1998) or urban economics. Wang (1999) remarks that central place theory does "treat cities as spaceless points" in order to analyze the structure of a system of cities. Hence, the major contribution of central place theory is to explain the existence of urban centers and of their hierarchical order. As Christaller's own analysis of Southern-Germany and other empirical studies show, the patterns he developed are not to be found in reality in this pure hexagonal form, but nevertheless in many cases central place theory describes the locations of towns and trade activity rather well.

Christaller makes the basic assumptions that the plane is homogeneous and that each customer will patronize the closest location. The former has often been criticized, even by Christaller himself, as obviously physical features like mountains or rivers also have an effect on central place locations and the respective market areas. If, however, the assumption were dropped, a modified structure would result, but still Christaller's basic result of a hierarchy of urban settlements remains true. The second assumption has developed into a standard assumption in location analysis, and it is also common to split the demand of a customer location between two facilities if both are at the same distance from the customer (Plastria 2001), e.g., in competitive location theory (for an introduction and overview, see Eiselt and Laporte 1989). In gravity models (Huff 1964) this assumption is modified to take into account aspects of attractiveness, for example of different stores.

In fact, closest center choice does not describe actual behavior, because people tend to go to places where they can satisfy different needs at the same time. In other words, multi-purpose shopping will usually take place (Eaton and Lipsey 1982), in contrast to the single purpose travel assumed by Christaller in his basic model. For this reason, most trips are made to higher order places instead of places of lower order. The same tendency can be observed regarding medical treatment: While medical services of different order are offered in different places, and hence the medical sector is organized hierarchically and fits Christaller's assumptions very well, people tend to go to a larger regional hospital instead of requiring treatment at a smaller and more local clinic, even if they have got only a minor health problem. This behavior, in turn, increases the size of high order places and leads to an even stronger hierarchy, as Christaller himself actually anticipated; however, this devel-

opment is not part of his basic theory but only of the subsequent discussion, see Sect. 20.2.2.3 above.

Moreover, with increasing industrial production and less expensive transportation, physical proximity of producers and customers became less important than Christaller assumed. Finally, customers usually are not uniformly distributed, but, mainly due to historical reasons, centers with higher numbers of inhabitants usually already exist.

Nevertheless, central place theory had a big impact on actual regional planning decisions in Germany, both during and after World War II. As Rössler (1989) reports, Christaller was involved in the development of Hitler's "General Plan of the East" at Himmler's "Planning and Soil Office." This was a plan to reconfigure the geography in Eastern countries such as Poland, where millions of inhabitants were forced to leave their homes and were relocated or deported to enable the setup of a new hexagonal structure of settlements.

After the war, in the 1960s and 1970s, central place theory remained the most important theoretical concept for German regional planning activities, as these activities concentrated on supplying the whole population with the necessary goods within a preset distance (or travel time). In applications to the planning of German regional structures, a maximum of three to four hierarchical stages of towns and settlements are considered. The concept was much criticized during the 1980s and 1990s due to its suggested lack of flexibility and because it was said not to take into account modern ideas of "sustainable development." However, it is still useful as a basic concept for political planning and activities in the areas of spatial and regional decision making, even if in adapted form (Blotevogel 2002). It has also been used for settlement planning in other countries, especially for the polders in the Netherlands (Yoshio 2006).

The major contribution of Lösch is the generalization of Christaller's hierarchically structured approach to a more flexible system of central places. In contrast to Christaller, Lösch's approach leads to different types of places which specialize in different goods, but are not in a strict hierarchical order. "Smaller" centers can also serve "larger" centers in his system, which is more realistic than Christaller's concept. However, the resulting pattern of locations is less regular than the one which is produced by Christaller's theory, and therefore it is more difficult to evaluate it empirically (Lang 2002). This is probably why most scientists, and especially those with an empirical background, focus more on Christaller's original theory and less on Lösch's generalized approach.

In contrast to Christaller, Lösch discusses different reasons for the existence of towns which are to be found in large individual enterprises, in agglomeration (because of advantages of larger numbers in sales and procurement), in advantages of certain sites in terms of natural conditions and the structure of the population, and in the fact that competitors will come into the market until there are no remaining rents and pure competition is reached. With this discussion, Lösch sets the stage for a theoretical foundation of the existence of towns, as it was developed later on by other authors.

20.4 The Impact of the Work of von Thünen, Christaller, and Lösch

As alluded to above, the work by von Thünen, Christaller and Lösch had a major impact on the subsequent development in different areas of economic theory. Some of the most important contributions which are based on their theories are presented in this section, in order to illustrate the significance of their seminal work.

20.4.1 The Impact of von Thünen's Work

Soon after it was published, many German economists such as Hermann (1832), Schüz (1843), and Roscher (1854), built upon von Thünen's work. Even now, von Thünen is very famous in Germany. There is even a "Thünengesellschaft" that, among other activities, publishes Thünen-Jahrbücher. Predöhl (1928), who integrates the problem of location choice into production theory, uses von Thünen's work as a founding pillar of his theory; however, while von Thünen concentrates on agricultural production and location, Predöhl's focus is on industrial activities.

Internationally, von Thünen's work was only little known until Isard (1956) and a little later Chisholm (1962) discussed it in their books and until, in 1966, an English translation was published. This was the same year as the translation of Christaller's book, which had appeared in its original German version more than 100 years after von Thünen's book!

Spatial pricing models as introduced, for example, by Beckmann (1952, 1968) can be said to have their origin in von Thünen's work, as they explicitly take into account the impact of transportation cost on the price structure, an idea which was first developed by von Thünen.

Von Böventer (1963) presents a common framework for agricultural and urban location theory. In his discussion, von Thünen's rings as well as Christaller's (and Lösch's) central place theory play an important role as basic models of economic theory. Therefore, it should be noted that agricultural and urban land use theories are based on the same ideas and have common roots, mainly in von Thünen's work, whereas industrial location theory goes back to different sources (Launhardt 1885 and Weber 1909).

Alonso studies the structure of cities in his book "Location and land use" (1964). Based on von Thünen's model for agricultural structures, he develops a monocentric city model with one central business district (*CBD*) in the middle, surrounded by a residential region. (An earlier contribution along similar lines goes back to Burgess (1923) who, mainly on a empirical basis, studies the structure of the City of Chicago.) Under the assumption of individual utility maximization, Alonso develops a system of resulting bid rents (land rents), i.e., the prices of the land at different distances to the center. Analogously to von Thünen's theory for agricultural land use, due to the cost of transportation the land rents for urban use decrease with

increasing distance to the centre, which leads to decreasing land use intensity, e.g. to taller buildings in the *CBD* and to smaller buildings with less floors in the outskirts. Depending on their intensity of land use and thus their productivity, industrial activities can be found in even larger distance from the city center in a ring surrounding the residential areas, if they require much space, or closer to the center, in a second ring around the retail and service area.

Alonso's book is the pioneer work in urban economics and location analysis, and monocentricity—a concept that corresponds to von Thünen's assumption of a single, centrally located city—for a long while remained a basic assumption in urban economics which was also used by Mills (1967), Muth (1969) and others.

Sinclair (1967) argues that von Thünen's theory and results, especially the decreasing intensity of land use at larger distances from the market, were still valid for underdeveloped areas, while it was not true for the industrialized parts of the world, as here the most important factor was urban expansion. This "urban sprawl" leads to the reversed pattern, i.e., to rings of increasingly intensive land use with growing distance from the city.

Krugman (1991), the founder of the "New Economic Geography" (*NEG*), a rather new branch of spatial economics, builds upon von Thünen's work, as do Fujita and Thisse (2002) in their work on agglomeration. The aim of the *NEG* is to "explain the formation of a large variety of economic agglomeration in geographical space, using a general equilibrium framework" (Fujita and Mori 2005). It is the general equilibrium modeling approach—following, in a way, the spirit of Lösch, but going much further in modeling the market mechanisms—that characterizes the "New Economic Geography" and distinguishes it from traditional Economic Geography as represented by von Thünen and Christaller. The explanation for the formation of centers (i.e., regions in which economic activities concentrate) and cities given by *NEG* is mainly based on increasing returns to scale and, therefore, imperfect competition, and on the existence of transportation costs. One major result is Krugman's "core-periphery model" according to which two rather similar economic regions can develop differently, due to a small advantage one of them has got, e.g., in terms of costs: one of them develops into an industrial agglomerated "core" and the other into non-industrialized periphery.

If there are different industries with differing scale economies or transportation costs, it can be shown that there is a tendency towards a hierarchical structure as it was already developed by Christaller. Based on von Thünen's, Christaller's and Lösch's results, Fujita et al. (1999) develop an integrated model of the economy, consisting of an industrial core and an agricultural periphery, and provide an explanation of the formation of cities and systems of cities in which, as in Krugman's approach, the importance of imperfect competition is emphasized.

Finally, it should be noted that von Thünen's ring model is still discussed and applied today, e.g., to explain the location of milk production (Block and Dupuis 2001). In the tradition of Alonso, the "Concentric Zone Model," which is based on Thünen's rings, is used with respect to urban structures to study the location of different economic activities in an urban setting as described above, or, for example,

to analyze the residential locations of different income groups assuming a circular city (de Bartolome and Ross 2007).

20.4.2 The Impact of Christaller's and Lösch's Work

Central place theory has acted as a foundation for many contributions regarding systems of cities. Christaller's seminal work was followed by many publications, one of them being the work by Lösch (1962). Christaller himself refined his concept, extended it to a European scale, and discussed the different aspects that influence the locations of agricultural activities (which will usually be dispersed in the "sphere of influence" of a central place), of industrial activities (which are to be found close to a centre or on a traffic line connecting central places) and of the central places (markets) themselves (Christaller 1950).

The ideas of Christaller were introduced to the English speaking world by Ullman in his paper "A theory of location for cities" (1941). (Note that, by publishing some major results in an English journal, Lösch (1938) reached a bigger readership at a slightly earlier stage.) Later on, these ideas are discussed by Isard (1956) who combines central place theory with Weber's results on production location, with market area theory and with von Thünen's results on agricultural location to derive the first unified and generalized location principle. A little later, a quantitative model for systems of central places is presented by Berry (1964).

The two aspects of Christaller's and Lösch's theories which influenced the subsequent literature most are (a) the hierarchy of locations or market places and (b) the hexagonal structure of locations and market areas. Some contributions to both areas are discussed below.

20.4.2.1 Hierarchy of Locations

Beckmann (1958) and Parr (1969) are interested in the sizes of the cities on different levels of hierarchy in Christaller's central place system. Based on the assumptions that the size of a city is proportional to the population it serves and that each city of a certain order has a certain number of "satellite" cities of the next lower order, Beckmann develops a system of multipliers by which the respective city sizes can be found. Beckmann and McPherson (1970) generalize the approach such that the number of "satellites," and hence the relation between the sizes of the market areas, is allowed to change from level to level. In other words, they modify Christaller's hexagonal structure in a way similar to Lösch's approach. Central place theory is therefore now often linked to the question of city sizes and urban growth (see, e.g., Nourse 1978). However, as Burns and Hfaly (1978) point out, centrality is not only related to population size, but should primarily be measured in economic units such as occupation and related incomes.

Von Böventer (1963) combines von Thünen's and Christaller's theories to develop "a hierarchy of villages within a ring formation for the commodities" or, if more than one town is taken into account, "hierarchies of agricultural villages within systems of interrelated Thünen rings." He emphasizes that in their pure form, von Thünen's theory can be mainly applied to the primary (agricultural) sector, Christaller's theory to the tertiary (services) sector and Lösch's theory to the secondary (manufacturing and production) sector. Regarding central place theory, this view is supported by Wyckoff (1989), who finds that it mostly held true for the service sector in Colorado at the end of the nineteenth century.

Beavon and Mabin (1975) restate and clarify some aspects of Lösch's theory, especially with respect to the development of the system of market areas of different hierarchical order. They emphasize that the "city-rich" and "city-poor" sectors are a constraint, and not a result, of Lösch's system. Moreover, they argue in favor of its use as a theory for urban development, i.e., as a concept which can represent and explain what they call the "internal tertiary structure" of a city.

In their work on spatial competition among shopping-centers, Eaton and Lipsey (1982) assume multi-purpose shopping behavior on the side of the customers and, based on this assumption, develop a hierarchy of shopping centers similar to Christaller's hierarchy of central places. In their seminal study, they concentrate on a one-dimensional market and on only two goods, and they develop important insights on agglomeration effects. Empirical studies regarding the attractiveness, growth and decline of shopping centers based on Christaller's central place theory and on the results of Eaton and Lipsey are presented, e.g., by Ryan et al. (1990) and Dennis et al. (2002).

20.4.2.2 Hexagonal Structure

Isard (1956) drops the assumption of a uniformly distributed population and concludes that the size (and shape) of a market area depend on the population density, and therefore will vary. A similar result is achieved by Rushton (1972). Friedmann (1961) continues the development of central place theory, concentrating on aspects of political, cultural, and social authority due to which the surrounding regions depend on the respective major center, and on the sub-centers which take care of some subordinate services. Again, the approach leads to an irregular structure of the resulting regions and centers. Allen and Sanglier (1979) study the influence of the introduction of new goods and services by simulation. Also their results do not show a regular pattern, but different irregular results. On the other hand, in his empirical study of the current German structures, Lang (2002) finds rather regular patterns of cities, but no obvious hexagonal structure.

Eaton and Lipsey (1975, 1976) point out that in a competitive environment, i.e., under the assumption of free market entry, no hexagonal market structure has to result in a two-dimensional market, given a uniform distribution of customers. While the hexagonal structure is the "planner's solution" that minimizes total transportation cost, and thus is efficient (Beckmann 1968), according to Eaton and Lipsey

it is not the solution that results from profit-maximizing behavior of the firms, at least when up to 19 firms are studied. However, Okabe and Suzuki (1987) come to the conclusion that for an even larger number of firms (up to 256 firms in their numerical tests), the "quasi-global equilibrium" configuration that results from spatial competition, will be similar to the hexagonal structure resulting from social planning. In an iterative procedure, Okabe and Suzuki apply Voronoi polygons in order to determine the market areas the competing firms can achieve from their current locations, then the firms relocate in turn if they can increase their market area by the respective move, and so on. The procedure results in a near-hexagonal structure; however, it should be noted that the two structures do not agree completely, but are only similar, and even in the case where the simulation is started with the socially optimal pattern, this pattern is actually destroyed during the process.

Drezner and Zemel (1992) examine the sequential competitive location problem in the plane in which two competitors can open multiple facilities each. Under the assumption of a uniform distribution of customers, the first competitor wants to choose his locations such that the second competitor is prevented from capturing too much of the market. The authors show that under these circumstances the hexagonal, honeycomb pattern is the best location structure for the first competitor to defend his market area.

Okabe et al. (1997) study systems of successively "inclusive" and "exclusive" hierarchical facilities. Here, an "inclusive" type of hierarchy is one, in which the facilities of higher order offer all services of lower order as well, and which occurs, e.g., in the medical sector. In the "exclusive" hierarchy, not all services of lower order are offered at each central place. As a result, the planning problem consists of the decision about the hierarchical structure of the facilities *and* about their spatial configuration in areas with uniform customer distribution. As it turns out, the regular triangular lattice as used by Christaller and Lösch is a basic feature of the solution for each stage of the "exclusive" problem. From the solutions of the different hierarchical stages, a solution of the "inclusive" problem can be derived which closely resembles the hexagonal structure suggested by Christaller.

Finally, Suzuki and Okabe (1995) show that a hexagonal structure also results for the continuous p-center problem in which the maximum distance from a user to his closest facility is to be minimized. Hence, the basic hexagonal structure that was first developed and studied by Christaller and Lösch is a characteristic feature of many different spatial planning situations which are of major interest to researchers and scientists up to this day. Moreover, central place theory is discussed and applied also in special areas of research such as sport tourism; see, e.g., Daniels (2007).

20.5 Future Research Directions

As the classical publications, as well as most of the work that followed, concentrate on a homogeneous plane with a uniform or regular customer distribution, future research might focus on the modification of these assumptions, such as non-uniform

demand and/or forbidden regions. Especially in the field of hierarchical and competitive location, this would lead to new and interesting insights which are more closely related to reality.

With the increasing globalization of all economic activities, global structures and systems of cities, and locations are increasingly the focus of economists and regional scientists. Therefore, central place theory and the theories building upon it can be useful to derive theoretical insights regarding the future development of these global structures, such as the pattern of future "global central places." Moreover, the ring concept that was originally developed by von Thünen and modified by Alonso for urban structures could be used to explain and perhaps also forecast the future development of those huge cities: for example, residential areas can be expected to be found farther and farther away from the city centers, while the centers' predominant functions are to host commercial activities.

In general, urban structures and their developments have to be studied to be able to plan and (politically) direct their growth and development. In particular, the development of "medium-sized cities" will be of interest, as it has not received as much attention as large cities have. It can be expected that, especially in Germany, central place theory will remain an important supporting tool for political decision making in regional planning, specifically with respect to the development of infrastructure in certain areas and with respect to the allocation of financial incentives to certain branches of industry.

Changes in transportation infrastructure have an important impact on both large scale and small scale planning and need to be taken into account in the future development of models in both areas. Here, the concept of "economic distances" as developed by Christaller may lead to further important insights, as the actual distances are less and less important, while the importance of "felt distances" increases. Due to the possibility of getting to literally every point on earth within a day or two, and of getting information from everywhere within seconds, some services do not have to be offered locally at all, but can be received by the customers even over a very long distance. It would be interesting to examine how the structure of the system of central places changes due to these developments.

Finally, environmental and ecological issues could also be incorporated in the respective approaches. This change of the planning objective will most likely lead to modified ring or network structures.

References

Allen PM, Sanglier M (1979) A dynamic model of growth in a central place system. Geogr Anal 11:256–272

Alonso W (1964) Location and land use. Harvard University Press, Cambridge

Beavon KSO, Mabin AS (1975) The Lösch system of market areas: derivation and extension. Geogr Anal 7:131–151

Beckmann MJ (1952) A continuous model of transportation. Econometrica 20:642–660

Beckmann MJ (1958) City hierarchies and the distribution of city size. Econ Dev Cult Change 6:243–248
Beckmann MJ (1968). Location theory. Random House, New York
Beckmann MJ, McPherson J (1970) City size distributions in a central place hierarchy: an alternative approach. J Reg Sci 10:25–33
Berry B (1964) Cities as systems within systems of cities. Pap Reg Sci 13:146–163
Block D, Dupuis EM (2001) Making the country work for the city: von Thünen's ideas in geography, agricultural economics and the sociology of agriculture. Am J Econ Sociol 60:79–98
Blotevogel HH (2002) Fortentwicklung des Zentrale-Orte-Konzepts. Forschung- und Sitzungsberichte ARL, 217. Akademie für Raumforschung und Landesplanung, Hannover, Germany
Burgess EW (1923) The growth of the city: an introduction to a research project. Publ Am Sociol Soc 18:85–97
Burns RS, Hfaly RG (1978) The metropolitan hierarchy of occupations—an economic interpretation of central place theory. Reg Sci Urban Econ 8:381–393
Chisholm M (1962) Rural settlement and land use, Hutchinson, London
Christaller W (1933) Die zentralen Orte in Süddeutschland, Fischer, Jena
Christaller W (1950) Das Grundgerüst der räumlichen Ordnung in Europa: Die Systeme der europäischen zentralen Orte. Frankfurter Geographische Hefte 24(1)
Coffey WJ (1998) Urban systems research: an overview. Can J Reg Sci 21:327–364
Daniels MJ (2007) Central place theory and sport tourism impacts. Ann Tourism Res 34:332–347
De Bartolome CAM, Ross SL (2007) Community income distributions in a metropolitan area. J Urban Econ 61:496–518
Dennis C, Marsland D, Cockett T (2002) Central place practice: shopping centre attractiveness measures, hinterland boundaries and the UK retail hierarchy. J Retailing Consum Serv 9:185–199
Drezner Z, Zemel E (1992) Competitive location in the plane. Ann Oper Res 40:173–193
Eaton BC, Lipsey RG (1975) The principle of minimum differentiation reconsidered: some new developments in the theory of spatial competition. Rev Econ Stud 42:27–49
Eaton BC, Lipsey RG (1976) The non-uniqueness of equilibrium in the Lösch location model. Am Econ Rev 66:77–93
Eaton BC, Lipsey RG (1982) An economic theory of central places. Econ J 92:56–72
Eiselt HA, Laporte G (1989) Competitive spatial models. Eur J Oper Res 39:231–242
Fejes Toth L (1960/1961) On the stability of a circle packing. Ann Univ Sci Budap, Sect Math 3–4:63–66
Friedmann J (1961) Cities in social transformation. Comp Stud Soc Hist 4:86–103
Fujita M (2000) von Thuenen and the new economic geography. Discussion Paper no. 521, Kyoto Institute of Economic Research. Kyoto, Japan
Fujita M, Mori T (2005) Frontiers of the new economic geography. Discussion Paper 27, Institute of Developing Economies, JETRO, Japan
Fujita M, Thisse J-F (2002) Economics of agglomeration: cities, industrial location and regional growth. Cambridge University Press, Cambridge
Fujita M, Krugman P, Venables A (1999) The spatial economy: Cities, regions and international trade. MIT Press, Cambridge
Hermann FBW (1832) Staatswirthschaftliche Untersuchungen über Vermögen, Wirthschaft, Productivität der Arbeiten, Kapital, Preis, Gewinn, Einkommen und Verbrauch. Anton Weber'sche Buchhandlung, München, Germany
Huff DL (1964) Defining and estimating a trading area. J Mark 28:34–38
Isard W (1956) Location and space-economy: a general theory relating to industrial location, market areas, land use, trade and urban structure. MIT Press, Cambridge
Krugman P (1991) Geography and trade. MIT Press, Cambridge
Lang B (2002) Die Untergliederung der Bundesrepublik Deutschland in strukturierte Wirtschaftsregionen. Peter Lang Verlag, Frankfurt, Germany
Launhardt W (1885) Mathematische Begründung der Volkswirtschaftslehre. Wilhelm Engelmann, Leipzig

Lösch A (1938) The nature of economic regions. South Econ J 5:71–78
Lösch A (1954) The economics of location. Translated by W.H. Woglom. Yale University Press, New Haven
Lösch A (1962) Die räumliche Ordnung der Wirtschaft, 3rd edn. Fischer, Stuttgart (1st edn published in 1940)
Mills ES (1967) An aggregative model of resource allocation in a metropolitan area. Am Econ Rev 57:197–210
Muth R (1969) Cities and housing. University of Chicago Press, Chicago
Nourse HO (1978) Equivalence of central place and economic base theories of urban growth. J Urban Econ 5:543–549
Ohlin B (1933) Interregional and international trade. Harvard University Press, Cambridge
Okabe A, Suzuki A (1987) Stability in spatial competition for a large number of firms on a bounded two-dimensional space. Environ Plan A 19:1067–1082
Okabe A, Okunuki K-I, Suzuki T (1997) A computational method for optimizing the hierarchy and spatial configuration of successively inclusive facilities on a continuous plane. Locat Sci 5:255–268
Palander T (1935) Beiträge zur Standorttheorie. Almqvist & Wiksell, Uppsala, Sweden
Parr JB (1969) City hierarchies and the distribution of city size—a reconsideration of Beckmann's contribution. J Reg Sci 9:239–253
Plastria F (2001) Static competitive facility location: an overview of optimisation approaches. Eur J Oper Res 129:461–470
Predöhl A (1928) The theory of location in its relation to general economics. J Polit Econ 36:371–390
Rössler M (1989) Applied geography and area research in Nazi society: central place theory and planning, 1933 to 1945. Environ Plan D 7:419–431
Roscher W (1854) Die Grundlagen der Nationalökonomie. J.G. Cotta'scher Verlag, Stuttgart, Germany
Rushton G (1972) Map transformations of point patterns: central place patterns in areas of variable population density. Pap Reg Sci 28:111–129
Rutherford J, Logan MI, Missen GJ (1967) New viewpoints in economic geography. Harrap, Sydney
Ryan DL, von Hohenbalken B, West DS (1990) An econometric-spatial analysis of the growth and decline of shopping centres. Reg Sci Urban Econ 20:313–326
Samuelson P (1983) Foundations of economic analysis. Harvard University Press, Cambridge
Schüz CWCh (1843) Grundsätze der National-Oeconomie. Druck und Verlag von C.F. Osiander, Tübingen, Germany
Schumpeter JA (1955) History of economic analysis. Oxford University Press, New York
Sinclair, R (1967) von Thünen and urban sprawl. Ann Assoc Am Geogr 47:72–87
Suzuki A, Okabe A (1995) Using Voronoi diagrams. In: Drezner Z (ed) Facility location—a survey of applications and methods. Springer-Verlag, New York, 103–118
Toregas C, Swain R, ReVelle C, Bergman L (1971) The location of emergency service facilities. Oper Res 19:1363–1373
Ullman E (1941) A theory of location for cities. Am J Sociol 46:853–864
von Böventer E (1963) Towards a united theory of spatial economic structure. Pap Reg Sci Assoc 10:163–187
von Thünen JH (1921) Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie, 2nd edn. Fischer, Jena, Germany. (The 1st edition was published in 1826)
von Thünen JH (1966) von Thünen's isolated state. Translated by Wartenberg CM. Pergamon Press, Oxford
Waldorf BS (2004) Path-breaking books in regional science. Pap Reg Sci 83:59–89
Wang F (1999) Modeling a central place system with interurban transport costs and complex rural hinterlands. Reg Sci Urban Econ 29:381–409
Weber A (1909) Über den Standort der Industrien. 1. Teil: Reine Theorie des Standorts. Mohr Siebeck Verlag, Tübingen, Germany

Wyckoff W (1989) Central place theory and the location of services in Colorado in 1899. Soc Sci J 26:383–398
Yoshio, S. (2006) Planning on Settlement Location in the Ijsselmeerpolders and Central Place Theory. Geogr Rev Jpn 79:566–587