ON THEORY VERIFICATION IN CHRISTALLER: ANALYSIS AND SPECULATION

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Abstract Applying spatial analytical methods to Christaller's (1933) original data, this paper re-examines the spatial arrangement of central places of the L-system of Munich. The results show that central places were not so hexagonally located as was predicted by central-place theory. The marked gap between the theory and its verification may have occurred because (1) his keen recognition of the German circumstances of the time requiring a national land planning theory, (2) his inductive discovery of the spatial order of medieval towns, and (3) his sense of place for southern Germany perhaps let Christaller to look at the region with a theory-ladden eye and to conclude prematurely that the theory was confirmed.

Key words: Walter Christaller, central-place theory, southern Germany, spatial analysis, topophilia.

1. Introduction

Christaller's (1933) text on spatial arrangement of central places, *Die Zentralen Orte in Süddeutschland*, largely consists of two chapters: theoretical and substantive. The theoretical chapter has been studied by examining its theoretical proposition (Beavon 1977) and by positively evaluating its dynamic aspect (Preston 1983 1985). The substantive chapter, which is rather redundant, has never been fully interpreted. The latter chapter makes the text so economic-geographical, however, that it should be read in a more precise way.

In the substantive chapter, after the central place distribution of each hierarchical level is minutely investigated by the five L-systems of Munich, Nuremberg, Stuttgart, Strasbourg and Frankfurt, the concluding sub-section of each L-system section investigates whether market, traffic or administrative principle is dominant. While reading these accounts, or after having read them, the reader looks at the well-known map (Map 4) of hierarchically-classified central place distribution in southern Germany at the end of the text. Since the theoretical schema has already been presented in the theoretical chapter (Baskin 1966, 66), the reader looking at the map can fall into the illusion that the same structure exists in the real world as in the theoretical world. That is, the reader comes to look at the real world with a theory-ladden eye.

If we think about the matter calmly, however, the features of each L-system —for example, the fact that G-places or K-places are rather uniformly distributed and their locations are determined by the market principle in the L-system of Munich (Baskin 1966, 188)— are not confirmed by submitting the result to a strict test. Nevertheless, it is a known fact that since Christaller (1933) many studies have repeatedly attempted to detect hexagonal structure in central place distribution in various parts of the world.

Fortunately, the original data used to measure centrality are provided at the end of the text (Christaller 1933). These data made it possible for succeeding generations to empirically test whether Christaller's (1933) discourse was supportable: Sarly (1972) found that market areas of all the central places above the H-place level became large with distance from Strasbourg; using spatial autocorrelation function, Gatrell (1979) detected a north-south directionality in the population distribution of southern Germany; Parr (1980), using the general hierarchical model, pointed out that the five L-systems did not have constant K-values; Woldenberg (1968 1971 1979) made a similar observation applying a mixed hierarchical model.

These studies suggest that the central place system in southern Germany of the 1930s contradicts the uniform demand density and rigid nested hierarchy postulated by Christaller's (1933) theory formulation. Up to now, however, no studies have focused on the *spatial arrangement* of central places itself there.

The first half of this paper thus quantitatively explores the spatial arrangement of central places in the core area of the L-system of Munich, using Christaller's (1933) original data. Even critical studies (Bobek 1935; von Böventer 1969) doubtful of the naive application of central-place theory to the real world under various conditions acknowledge that central places might be located, according to the theory, in the Bavaria region; this possibility was actually admitted by Christaller (1972, 609) retrospectively.

In the latter half of this paper, the implication of the results derived from the quantitative analyses will be discussed with reference to Christaller's inner and outer worlds in building central-place theory. Together with Christaller's (1972) own retrospective article, recent biographical studies (Preston 1992; Rössler 1989) on Christaller's career and his theory contribute to the discussion to a great extent. Accordingly, this paper would result in suggesting details of Christaller's (1933) theory formulation through spatial analyses of central place location in a representative area.

2. Methodology

The study area is a semi-square area around Munich, extending 140 km from east to west and 130 km from north to south; gently rolling heights and plains form its topographical features (Fig. 1). Precisely speaking, the area is bent 5 degrees counterclockwise from the east and west directions. We are concerned with 296 centers at 8 hierarchical levels, including the lowest order or H-level centers as auxiliary central places; the names of three H-level centers, Diedorf, Lohkirchen and Schlehdorf, are not listed in Table of Appendix, but only their locations are shown by Map 4 in Christaller's (1933) text. They roughly amount to one half of the total number of centers in the

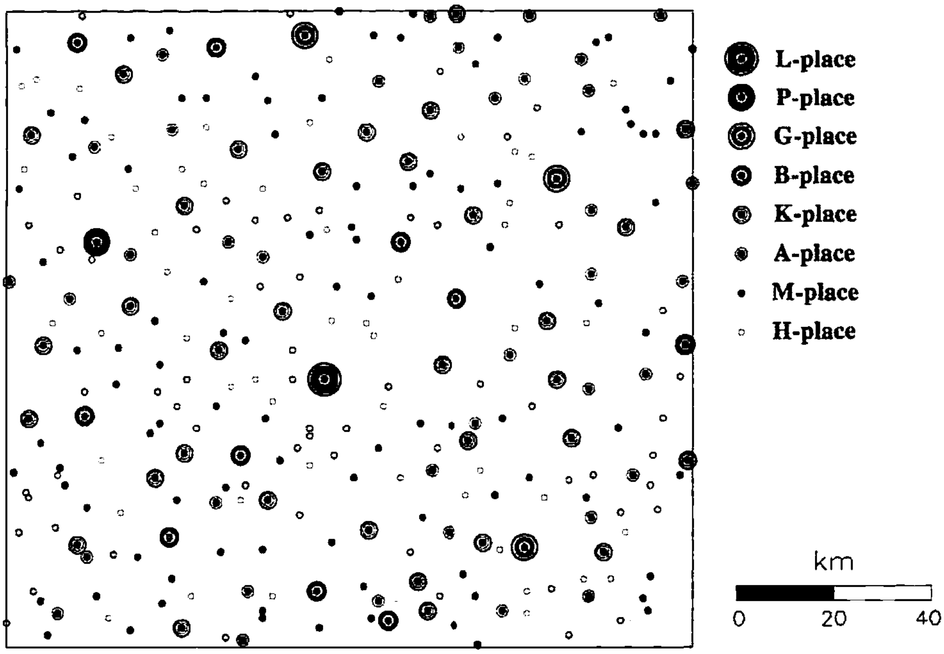

Fig. 1 Location of central places in Munich and its surroundings, early 1930s

L-system of Munich which Christaller (1933) originally identified. In addition to one L-level place, Munich, there are four major centers: a P-place, Augsburg, located northwest of Munich; and three G-places, Ingolstadt, Landshut and Rosenheim, located north, northeast and southeast of Munich, respectively.

Each center's location is identified based on *Andrees Handatlas* published in 1930 and on German topographical maps on the scale of 1:50,000. Four analytical methods are applied to these locational data to investigate the spatial arrangement of central places.

The first is the general hierarchical model (Parr 1978 1980), which permits us to theoretically infer hierarchical size-distribution and inter-center distance by hierarchical level. According to that model, the number of centers, f_m, at level m is derived as follows:

$$f_m = \prod_{i=m}^{N-1} K_i - \prod_{i=m+1}^{N-1} K_i \quad (1)$$

where N is the number of hierarchical levels and K_i is the varied K or nesting factor at level i.

Given both K_i and the average inter-center distance, d_1, between the lowest-level centers, a theoretical distance, d_m, between centers at level m can be estimated:

$$d_m = d_1 \prod_{i=1}^{m-1} \sqrt{K_i} \quad (2)$$

Spatial patterns of centers are captured by nearest-neighbor measure (King 1962) and second-order analysis (Getis 1984). Nearest-neighbor measure, R, is defined as

$$R = d_0/(1/2\sqrt{D}) \tag{3}$$

where d_0 is the mean nearest-distances between centers and D is density of centers. An aggregated pattern is confirmed when R-value statistically-significantly differs from 1 and approaches 0; a random pattern, when R-value does not statistically-significantly differ from 1; and a uniform pattern, when R-value statistically-significantly differs from 1 and approaches 2.149.

Second-order analysis, first of all, estimates $L(d)$ corresponding to a distance, d, between a given pair of two centers, which is inferred from the number of centers within the latter distance in the case where centers are distributed according to Poisson distribution:

$$L(d) = \sqrt{A \sum_{i=1}^{n} \sum_{j=1}^{n} I_{ij}/[\pi n(n-1)]} \tag{4}$$

where A is areal size of the study area, n is the total number of centers, and $\sum_{i=1}^{n} \sum_{j=1}^{n} I_{ij}$ is the number of centers within a distance (d) from all the centers i's to all other centers j's.

Then a relationship is investigated between d and $L(d)$ over all the distances between all the pairs of centers. Spatial patterns are judged on the basis of a curve showing the relationships between d scaled on a horizontal axis and $L(d)$ on a vertical axis: a random pattern is confirmed when the curve fluctuates within an error band which diagonally extends in the 45 degrees direction from the coordinate origin, an aggregated pattern when the curve statistically-significantly deviates above the error band, and a uniform pattern when the curve statistically-significantly deviates below the error band. This paper follows a convenient computing procedure for a rectangular area (Boots and Getis 1988).

As regards forms of market ares, Voronoi polygons (Okabe *et al.* 1992) are drawn around all the centers, assuming that the German consumers of Christaller's time were served by the nearest centers; note that M-level market areas with a range of 5km or one trip-hour (Baskin 1966, 160), whose geometrical shapes are similar to Voronoi polygons with gaps, are delimitated in Map 3 of Christaller's (1933) text. The contact number of a polygon or the number of neighbors of a center is counted by the hierarchical level, from which the geometrical shape of market area, in a topological sense, can be deduced.

3. Results

Table 1 shows the values for the set of varied nesting factors $\{K_i\}$ and the theoretical frequency distribution of central places predicted by the general hierarchical model. It is apparent that unlike Christaller's (1933) explication for the L-system of Munich suggesting that the market principle operates through all the hierarchical levels,

Table 1 Central place frequencies for various L-system of Munich

Hierarchical level	The whole L-system including Austria and Italy[1)]			The partial L-system within southern Bermany[1)]			The partial L-system in the core area		
	Observed frequency[2)]	Theoretical frequency[2)]	$\{K_i\}$	Observed frequency[2)]	Theoretical frequency[2)]	$\{K_i\}$	Observed frequency[2)]	Theoretical frequency[2)]	$\{K_i\}$
L	1	1	—	1	1	—	1	1	—
P	2	2	3	1	2	3	1	1 (or 2)	2 (or 3)
G	8	9	4	6	6	3	3	4 (or 3)	3 (or 2)
B	27	24	3	18	18	3	10	12	3
K	89	108	4	59	54	3	33	36	3
A	122	144	2	81	81	2	37	54	2
M	270	288	2	180	162	2	98	108	2
H	288	288	$1\frac{1}{2}$	192	162	$1\frac{1}{2}$	113	108	$1\frac{1}{2}$
Σ	807	864		538	486		296	324	

1) Parr(1980)
2) Number of central places of the hierarchical level concerned.

central places are not distributed with the constant K-value of 3. The market principle is dominant only in the high and middle hierarchical levels; but the low-level hierarchical structures are $K=2$ and $K=1(1/2)$, implying the existence of square and triangular market areas, respectively (Parr 1980).

According to Parr's (1980) theoretical investigation, a result that hierarchical structures of successive levels of A-place and M-place are $K=2$ is due to the structural change that a single hierarchical level with $K=4$ was dissolved into two hierarchical levels with $K=2$, keeping pace with expansion or reduction of the threshold ranges of the central functions. A result that hierarchical structures of the lowest H-level centers are $K=1(1/2)$ is interpreted to mean that centers lower than the once lowest level were not grown to form a full level. Compared with the $\{K_i\}$ sets of the whole L-system of Munich developing in Austria and Italy as well as in southern Germany and with the partial L-system of Munich developing within southern Germany (Parr 1980), hierarchical structure in the study area is similar to the latter.

Table 2 shows the average distances between the nearest centers by hierarchical level. Except for the lowest H-level, the average inter-center distances are shorter than those in Christaller's (1933) central place system with $K=3$ structure. If, using varied K-values already obtained, the average distance between the nearest H-level centers, 5.43km, is put into equation (2), then the theoretical inter-center distances by hierarchical level are successively derived (see Table 2). The differences between the actual and theoretical inter-center distances from M-level to B-level are as little as about 1 km, so that the general hierarchical model well approximates the L-system of Munich, at least in the study area, in terms of spacing of central places.

An application of the general hierarchical model presupposes a uniform distribution of central places. In order to examine this aspect, their spatial patterns are ascertained by nearest-neighbor measure. The results shown in Table 2 reveal that the spatial patterns of all the hierarchical levels statistically-significantly differ from random

Table 2 Nearest-neighbor measure values (R) and nearest-neighbor distances

Hierarchical level	Number of central places[1]	R	Average nearest-neighbor distance (km)	Nearest-neighbor distance for varied K-system (km)[2]	Nearest-neighbor distance for $K=3$ system (km)
P	2	—	54.28	69.11 (or 56.43)	108
G	5	1.85**	55.86	39.90	63
B	15	1.40**	24.43	23.04	36
K	48	1.45**	14.14	13.30	21
A	85	1.37**	9.99	9.41	12
M	183	1.34**	6.67	6.65	7
H	296	1.39**	5.43	5.43	4

** Significant at the 0.01 level

1) Number of central places of the hierarchical level concerned or higher

2) Given 5.43km, the actural nearest-nighbor distance of H-place, the nearest-neighbor distances for varied K-system are calculated using the varid K-values estimated for the core area shown in Table 1.

pattern but approach uniform pattern. It is therefore confirmed that the application of the general hierarchical model is appropriate and that the results are reliable.

Nearest-neighbor measure is an analytical method to judge spatial patterns on the basis of distance to the nearest center only, and does not take into account all the distances between all pairs of centers. To overcome this shortcoming, second-order analysis is further performed to measure spatial patterns of G-level centers or lower. In the cases of G- and B-levels, although curves showing the relationships between d and $L(d)$ almost fluctuate below the diagonal lines, they shift within the error band of the 0.05% significance level (figures are omitted); centers of both hierarchical levels are distributed in a random manner. With hierarchical descending from K-level, the diagonal curves tend to be located further below the error band, and this trend becomes especially marked for lower levels of M- and H-centers (for K-level, see Fig. 2); apparently middle- and low-level centers are uniformly distributed.

Finally, Voronoi diagrams are constructed by hierarchical level lower than B-level to explore the hexagonal structure of market areas. Except for H-level, clear hexagonal patterns do not emerge for any hierarchical level (figures are omitted). Hexagonal patterns are locally maintained in areas west and northwest of Munich only for H-level (Fig. 3). This could be partially attributed to a fact that there exists a spatial regularity in the G-system of Augusburg adjacent to that of Munich, as pointed out by Christaller (Baskin 1966, 180–181).

Relaxing shape conditions to detect the hexagonal structure in a topological sense, contact numbers of Voronoi polygons are counted by hierarchical level (Table 3). Since polygons truncated by the boundary of the study area should be excluded, it is better that counting is limited to A-level or lower with as many as 50 or more polygons. For A-, M- and H-levels, the contact number of 6 shows the highest frequency of polygons. Both A- and M-levels' frequencies of polygons with the contact number of 6 are, however, about 30% of the total polygons concerned, which are not so different from those of random

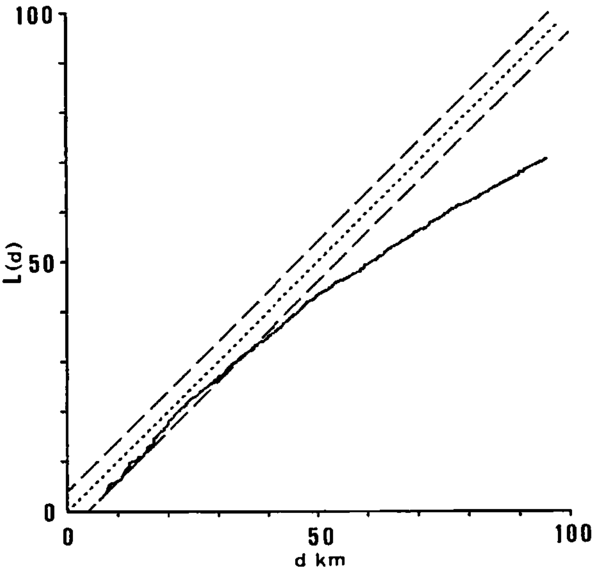

Fig. 2 Graph of $L(d)$ and the error band (dashed lines) at the 0.05 significance level of K- level centers in southern Germany
The dotted line shows the Poisson values of $L(d)$.

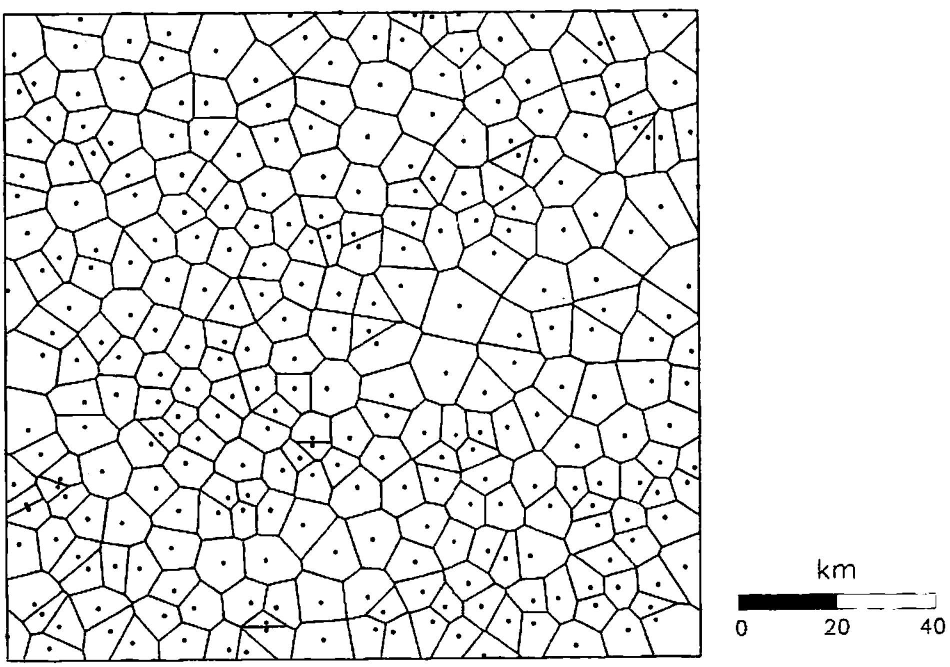

Fig. 3 Voronoi diagram for H-level centers or higher

Table 3 Relative frequenies of contact numbers of Voronoi polygons[1)]

Contact number	B-level	K-level	A-level	M-level	H-level	Random Voronoi polygons (Vincent *et al.* 1983)	Random Voronoi polygons (Boots and Murdoch 1983)
3					1.3	1.1	1.1
4		14.3	10.7	11.2	4.3	11.5	10.6
5	50.0	28.6	30.4	29.9	28.5	26.5	25.8
6	25.0	25.0	32.1	31.3	38.3	29.6	29.9
7	25.0	28.6	19.6	16.4	22.1	19.2	19.7
8		3.6	5.4	9.0	4.7	8.5	9.2
9			1.8	1.5	0.9	2.8	2.9
10				0.7		0.7	0.7
11						0.1	0.1
12						0.03	0.03
13							0.004
14							0.002
Number of the central places or points considered	4	28	56	134	235	8,941	50,000

1) Central places of the hierarchical level concerned or higher are considered and polygons truncated by the boundary are excluded.

Voronoi polygons (Vincent *et al.* 1983; Boots and Murdoch 1983); even if polygons with the contact numbers of 5 and 7 are added to frequency counting, the result is almost the same. H-level's frequency of polygons with the contact number of 6 is, on the contrary, close to 40%: the frequency is as much as 10% higher than those of random Voronoi polygons. Furthermore, if frequencies of the contact numbers of 5 and 7 are taken into account as well as that of 6, then the total frequency amounts to about 90%. Therefore a topologically hexagonal structure of market areas is locally observed only for the lowest hierarchical level— that is, only when all the central places are considered.

4. Discussion: Between Theory and Its Verification

It turns out that central places, especially at the middle level or lower, are uniformly distributed to form a varied K hierarchical system in the core area of the L-system of Munich. But a hexagonal structure of market areas locally emerges at the lowest level only. It is thus concluded that unlike Christaller's (1933) explication, the central place system in the study area does not constitute a constant $K=3$ system. Although the Bavaria region has been unanimously acknowledged as one of the representative areas for which the central place model well describes the settlement location (Bobek 1935; von Böventer 1969), at least the spatial analyses based on Euclidean distance could not confirm a clear hexagonal network of central places. A more sophisticated method would have correctly detected a hidden spatial order.

To Christaller, however, Euclidean distance is undoubtedly the measure to judge spatial patterns: for example, he assumed a circle of 62km radius —the range of the typical central goods of the P-place— around Munich and looked for the G-places on that ring; the same procedure was repeated for hierarchical levels higher than A-level (Baskin 1966, 175-185). If we say that appropriate spatial analytical methods had not yet been devised in his era, that would be the end of it; but I would rather like to investigate the gap between theory and its verification, as observed in Christaller's (1933) text: why did Christaller allow himself to look at the same structure in the real world as in the theory? Why was he able to determine it?

Social milieux

For what purpose did Christaller write his text? The preface, which is not translated in the English text (Baskin 1966), says that originally it was intended as an economic or national study whose main viewpoint was to look for an economic-theoretical foundation for organizing a rational national administration system and for reorganizing German land with the goal of simplification of national life (Christaller 1933). Evidently the aim was to develop a guide for national land planning. The ultimate aim of establishing economic-geographic laws useful in economic and political practice is explicitly stated at the end of conclusion (Baskin 1966, 201-202). It is thus apparent that Christaller was fundamentally oriented toward applied research. It is true that his research inclination would later lead to his own commitment to Nazi planning activities, and especially to developing the basic plans for German settlement in occupied Poland (Rössler, 1989), without fully acknowledging the larger processes of which he was part (Fehl 1992, 97).

Considering the conditions in Germany in the early 20th century, when his text was written, makes his purpose fairly understandable. Germany had been defeated in World War I; its territory was reduced in 1919 after the Treaty of Versailles to 87% of the prewar state, and its population to 90% (Freeman 1987, 8). As is well known, in this situation the Nazis fanatically propagandized that since its land was too small for its population, German territory should be re-extended, in a shrewd adaptation of German geopoliticians' idea of *Lebensraum* (Bassin 1987). Germany underwent manifold changes as a result of territory cession, and Christaller (Baskin 1966, 124) acknowledged that alteration of the borders caused central place systems to change and in turn influenced various aspects of the nation.

The defeat of the Second German Reich brought about the formation of the Weimar Republic, but its state constitution was greatly imbalanced: 17 States or *Länder* constituted the Republic, but Prussia had 60% of both its area and its population scattered among fragmentary regions, while at the other extreme was the tiny state of Schaumburg-Lippe (Freeman 1987, 7). Internally, Prussia's status was needed to be degraded in order to ease this politico-administrative imbalance, while at the same time a centralized nation was needed for dealing with the external world. In conjunction with administrative centralization, a united municipal code over the country was desired, and the Prussian municipal code system was provisionally enacted in December 1933 (Sugimura 1935); it was also in this year that *Die Zentralen Orte in Süddeutschland* (Christaller 1933) was published and the Nazis came into power. Enactment of the new united municipal code is expected to achieve simplification of local administrative systems and sound finances through alteration of municipal boundaries and reorganization of administrative areas, whose symptoms had been mentioned by Christaller (Baskin 1966, 161, 167-168).

Since the end of the 19th century, rural-to-urban migration had been remarkable, and population began to be concentrated in large cities; Berlin was growing remarkably while numbers of out-migrants increased in the eastern regions. As the result, a marked regional inequality was developing in terms of population distribution and economic growth. In 1902 the German Garden City Society, modeled after that in England, was established in Berlin to promote metropolitan decentralization into surrounding areas in order to relieve urban concentration; the Garden City movement spread throughout Germany in the 1910s (Bollerey and Hartmann 1980). As the Greater Berlin Planning Authority was organized, in 1910, to solve urban problems in the capital, urban planning was gradually taken up for discussion in Germany. In 1920, Greater Berlin City was established and the Greater Berlin Planning Authority was reorganized into the Greater Berlin Association: a planning authority for the Ruhr industrial areas was also organized, and afterwards similar regional planning agencies were set in motion in various parts of the country (Soda 1984). Regional planning was not yet sufficiently systematically coordinated, however, to end regional inequality. According to Christaller (Baskin 1966, 126), these planning organizations had been created more or less in response to specific local situations: they lacked theoretical bases, and their long-term goals were unclear. Christaller pointed out that German national land planning lacked the goal of distributing market regions to the respective centers (Baskin 1966, 131).

In this social milieu, Christaller, perhaps being most worried about the country, seems to have decided to propose the principles that would achieve the highest rationality in the economy of *national* land planning (Baskin 1966, 126). Closely related with his theory were surely both his devotion to socialism via the pacifism burgeoning in response to World War I and his experience of working in a construction firm and city planning in Berlin (Hottes *et al.* 1983; Christaller 1972); as regards the former, note that the concepts of urban planning originated from the social reform movement. As a natural outgrowth of this interest, Christaller attempted to explore a new field, applied administrative geography, in the 1930s after completing his dissertation (Preston 1992).

Medieval spatial order

Christaller's academic consciousness required the idea that decentralization of cities and dispersal of industry were indispensable to solving the problems due to regional inequality brought about by rapid urbanization. He contended that the centralistic order of older towns was no longer apparent as urbanization progressed in Germany (Baskin 1966, 15). To him, the centralistic order was a beautiful principle universally ruling not only the material world but also the human world. The apparent centralistic order had once been observed in the medieval European town, where a church or a city hall rose in the central square and residential areas radiating from it were enclosed by a wall at the periphery. As population increased, the urbanized area extended outward, and the wall was destroyed, the centralistic order disappeared at least superficially. Christaller (Baskin 1966, 15-16) thought that the centralization as a hidden order is discernible if grasped in terms not just of morphology but also of function, since the organization of human community is centralistic in principle.

Needless to say, in the Middle Ages a cosmology underlay the centralistic order of medieval European towns (Tuan 1974; Sack 1976). In ancient Europe it was thought not only that nature made parts of the human body in proportion to the whole body, but also that the human body had a center at the navel; a line drawn around that center and connecting the extended arms and legs results in a square. The human body thus has a geometrical order represented by both a circle and a square (Wakakuwa 1979). The ancients imagined the order according to the human scale whenever they built a sanctuary. The idea that the ideal order of a city, a building and the human body as well as the geometrical order of the whole universe could be captured in a consistent analogical way was passed down from the Ancient times to the Renaissance in Europe, and popularized by the Roman architect Vitruvius. Typical is the radial-concentric town in the European Middle Ages. The idea behind European town plans is one that the city becomes humanistic-cosmic by approaching some geometrical patterns as the ideal shape, implying the realization of a beautiful harmony of microscopic and macroscopic cosmos. Ebenezer Howard's (1898) garden-city plan was a kind of its modern version (Tuan 1974, 159): Howard's (1898) Social City diagram exhibits the same hexagonal pattern and hierarchical ordering of urban settlements as Christaller's (1933) central-place theory (Fehl 1992, 97).

The fact that Christaller (Baskin 1966, 14-16) took, in a sense, the theoretical chapter from the centralistic order embodied in medieval towns implies a revival of the medieval spatial order. However, it is really another medieval spatial order that Christaller inductively discovered in conceiving his theory, as he confessed in his autobiographical article (Christaller 1972, 607-610). Through mapping work he recognized that the minimum radius of the market area was 4 to 5 km. This distance corresponds to the distance that can be traveled in one hour on foot (Baskin 1966, 159-160). Christaller, who had also recognized earlier that connecting cities of equal size by straight lines resulted in a map filled with triangles, which then crystallized as hexagons, could then estimate the distance between the lowest-order central places or M-level centers, 7km. Thus the theoretical distance between K-level central places, 21km, was derived by successively multiplying the distance between lower-ranking central places by 3, as suggested by the $K=3$ system. Christaller (1972, 607) was surprised to discover that this distance almost corresponded to the distance covered in a day by a cart in the Middle Ages.

Certainly Christaller rediscovered the medieval spatial order in his theoretical system. Then he established a substantial academic connection with Robert Gradmann, his doctoral supervisor and also an authority on German settlement geography. Gradmann (1931) discussed the origin of medieval towns in *Süddeutschland*. According to Gradmann (1931), the majority of present-day towns had already existed in southern Germany at the end of the Middle Ages: they served long-distance trade, local market trade, or defense and administration (Dickinson 1964). It is Gradmann's (1931) contention that local market trade played the major role in the development of the town. His argument, in fact, is closely related with central-place theory because in terms of the theory, it is the market principle —the primary law— that determines the distribution of towns serving local market trade; the traffic principle, as a secondary law, determines that of towns on long-distance trade routes, and the administrative principle, as the other secondary law, determines that of towns for administration. That is, from an economic-geographic perspective central-place theory gave a theoretical basis to Gradmann's (1931) settlement study of southern Germany made from a historical perspective. This seems to be one of the reasons why Gradmann willingly accepted the doctoral supervision of Christaller in spite of the methodological differences between them. As shown by frequent citations of Gradmann's work in the text (Christaller 1933, 11, 23, 31, 52, 64, 79, 124, 143, 150, 151, 257, 261), Christaller's literature review work convinced him that his theory would be correct in the light of empirical evidence.

Topophilia for Christaller

Southern Germany, where traces of medieval central place distribution remained here and there, was also Christaller's *living space* through his life. He was born in 1893 in Berneck in the Black Forest, about 50km southwest of Stuttgart, attended a grammar school in Darmstadt, and studied philosophy and political economics at universities in Heidelberg and Munich (Christaller 1972; Hottes *et al.* 1983; Hottes 1983); these town and cities are all in southern Germany. From 1914 through 1928 he left southern Germany to serve on the front lines during World War I, and after the end of the war he worked in Berlin. In 1928, returning to southern Germany, he studied at the university in Erlangen, north of Nuremberg. He spent almost two-thirds of his career in southern Germany before completing his dissertation, so he was familiar with the region.

Christaller conceived his theory not just by calculating and mapping at his desk; he also used to hike on weekends in the Frankish Alps near Nuremberg, which may have given him new ideas for breaking bottlenecks in theorizing as well as refreshing him (Christaller 1972). This hiking also seems a kind of field observation to help theory-building, judging from a line in his autobiographical article: "It [many an idea] was connected in my memory to some forest path or other, just where I was, where the sun cast its light patches through the foliage onto the earth, or with some view or other from a rocky height, or with some, perhaps, field path of no importance" (Christaller 1972, 609). Desk work using maps on weekdays and fieldwork on weekends together made up a weekly rhythm in terms of time-geography, and he may have come to have the feeling that outdoors and maps were harmonious, so that self and landscape fused into one, for him, to shape an intimate space in and around Nuremburg and Erlangen.

The acts of reading maps and watching scenery are based on a good command of the sense of vision; those of drawing triangles connecting equal-sized cities on a map with a pen(cil) as an extension of the fingers and of walking about the countryside by putting on one's shoes as an extension of the feet are based on a good command of the sense of touch. Using the number of telephone connections to measure centrality —which is relevant to the sense of vision, by nature, in that centrality is *invisible*— is far from unrelated to the sense of hearing. While the network of telephone circuits themselves physically consists of a hierarchical structure, in those days before the dial telephone, when connections were made via operators, the speaker would unconsciously have perceived this hierarchical structure through the receiver as an extension of his ears. It is not clear whether telephones were still used as local media or already were countrywide media in the 1930s in southern Germany. If the case was the former, the very act of a making phone call was no more than perceiving the center-periphery relation in a local area; if the latter, the hierarchical structure of central places would be perceptible. Following Tuan (1977, 18), Christaller was likely to conceptualize the concrete reality of the region through at least the three senses of vision, touch and hearing, as well as with the active and reflective mind.

In this connection, Lösch's (1954, xv-xvi) words in the preface of his text are useful to remember: "My youthful experiences in a little Swabian town constitute the real background of this book. I am convinced that we rarely learn to know any conditions as intimately as those among which we grew up. We can judge with certainty only a small understandable and familiar world like this.... My Swabian homeland constitutes such a world in miniature, if any economic landscape at all can be said to do so....I dedicate this book to the land of my birth, the land that I love." These sentences illustrating that affective ties with familiar environment or topophilia (Tuan 1974) are a source for building a theory reveal that the individual, the idea and the region are rarely far removed in the geographical sciences, as pointed out by Haggett (1990, 70). Taking into account that Lösch's native place, Heidenheim, is in southern Germany, like that of Christaller and that he proposed a similar theory concerning settlement location, the same relation between theory formation and topophilia could be true of Christaller.

4. Concluding Remarks

This paper has revisited the central place distribution in the 1930s in southern Germany — Munich and its surrounding area, applying the general hierarchical model, nearest-neighbor analysis, second-order analysis and Voronoi polygons to Christaller's (1933) original data. It turns out that the clear hexagonal network of central places which Christaller (1933) proposed could not be found, although the places were rather uniformly located. Examining the maps concerned, it seems difficult to detect the hexagonal structure even in other L-systems of southern Germany.

In spite of this, it seems possible to conclude that (1) Christaller's determined will to formulate an urban settlement location theory that would contribute to the national land planning earnestly desired at that time, and (2) his inductive discovery of a spatial order of medieval towns through desk work, literature review and fieldwork, with his familiar southern Germany as the study area, led him to assume that a hexagonal network of central places covered the real region, and to discuss in detail deviation of the actual central place system from the theory. Above all, because of the tautological fact that the theory was tested only in southern Germany where data were collected to induce it (Christaller 1972, 607-608), as a natural consequence Christaller could not reject it at all; in this vein we might be permitted to read Christaller's (1933) text retroactively from the substantive to theoretical chapter.

Central-place theory advocates, in a sense, a revival of the medieval spatial order. Curiously, this coincides with Gottfried Feder's (1939) planning study on developing a new town with 20,000 inhabitants explicitly imaging a circular walled medieval town; Feder was a famous Nazi ideologue who was involved in drawing up the Nazi Party Platform in 1920, laid the foundations of German national land planning after the middle 1930s (Soda 1984), and participated in the study group organized by Christaller in the Reich Association for Area Research in order to discuss applicability of central-place theory to settlement planning (Rössler 1989, 422). What attracted the Nazis, who dreamed of the millennium or a new European order which they saw as the second advent of the Holy Roman Empire, to central-place theory may have been its implicit appeal to the medieval order.

Central-place theory depicted an urban network more tightly structured than the medieval urban network — that is, an urban network *spatially* dispersed and *hierarchically* ordered — and might to be expected to be useful in the Nazis' national land planning aimed at *centralization* of government as well as metropolitan *decentralization*. The fact that academics working in the Nazi planning organization soon made responses to the advent of Christaller's (1933) thesis, whereas only a few geographers noticed it in the 1930s (Rössler 1989, 422-423) evidences that central-place theory takes on much of the character of national land planning theory. German urban or regional planners with a thorough knowledge of Howard's (1898) diagram of the Social City must have thought that central-place theory was an extension of the garden-city concept and accepted it readily. It is not too much to say that Christaller's primary concern lay in proposing the theory, and that its empirical substantiation in the real world was secondary to that end.

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