DISTANCE CONCEPTS IN SOCIO-ECONOMIC SPACE ANALYSIS

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The purpose of this paper is to reconsider some concepts of distance as an element of socio-economic space.

Almost by definition the concept of distance is the cardinal problem in economic geography. Watson (1955) speaks of geography as a "discipline in distance". A discussion of the importance of distance in geography can also be found in works of Ajo (1957), Bunge (1962), Nystuen (1963), Olsson (1965a) and others. Isard (1960a, p. 9) stated that "distances... are key concepts" for regional science.

The concept of distance is strictly related to the concept of space. While the link between the concept of space and physics is familiar to all, the problem and the concept of space in theoretical analysis of social and economic systems is now coming to be acknowledged and interpreted in a different manner, far of the traditional way of thinking in geography.

The concept of space has extremely broad connections and it is not capable of an explicit definition, that is suitable for all purposes. In the broadest abstract sense it differs little from set, which are made to conform to certain postulates.

Two examples of spaces of a more abstract nature are:

(1) metric space, characterized by a distance measure associated with each pair of elements;

(2) topological space, in which each element possesses a neighbourhood and limit points play a dominating role.

What are the concepts of space which are used in the theoretical analysis of social and economical phenomena being a subject of economic geography and regional science? In fact the diversity of phenomena of group of phenomena in earth space is so complicated that depending on our points of view, we use various mathematical or geometrical models of space.

Some authors mention several types or aspects of such space. For example Sorre (1957) distinguished three most important: geodesic, geographical and socio-economic spaces.

According to Dziewoński (1965, p. 124) the geodetic space is an abstract geometrical concept, pertaining only to general shape of the earth. Its abstract, homogenous and continuous in all directions character represents qualities which are of very great value in a reference framework when dealing with the other purposes.

The geographic space represents the earth surface in its complex physical variety; is not homogenous and not continuous.

The concept of socio-economic space is at a higher level of generality than the concept of geographic space. The term socio-economic space means this total, integrated social and economic space which is created by the activities of a human community. It is not homogenous and discrete.

Both spaces socio-economic and geographic are empirical. Empirical space is nothing other than a multitude of facts existing at a given time and showing certain type of interrelation. Form and properties of such space vary with the functional meaning of the interrelation being considered. In this sense space is shaped by the functional interrelations and there will be as many varieties of socio-economic space as fundamental relations (Friedmann, Alonso 1964, p. 19).

A strong emphasis was put on rigorous distinction between geonomic space and economic spaces by Perroux (1950). He attached the usefulness of the concept of geonomic space in economic analysis, called it "banal" space and accused it of creating the illusion of the coincidence of political space with economic and human spaces.

Really there is not so sharp and clear contradiction between both types of spaces. Dziewoński (1962, p. 49) suggested that they are topologically equivalent, although in some cases, for instance when we identify the socio-economic space with the ecumena of human community, one is equivalent only to a part, i.e. to a subpart, of another. There are also many phenomena in economic, geography, regional science and sociology which can satisfactorily be interpreted as properties of geographical space or of its parts. The most successful interpretation have come from social physics.

Some authors postulate to develop the general concept of socio-economic "superspace". But it is the question whether we obtain much more real solutions if we could establish the relations of general socio-economic space. The idea of the operational socio-economic superspace is rather some distant dream.

What really we could know presently as operational concept is the multitude of spatial relations for different types of social and economic phenomena.

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Distance is a fundamental geographical property. As a spatial organization geographic patterns necessarily involve distance in some form or another. It is that many geographic and socio-economic concepts and models explicitly or implicitly incorporate element of distance. This is strictly connected with the geographic importance of relative location and relation of human interaction on distance. But there is no agreement as to the functional form of the relation between distance and interactions. Some authors refer to friction of distance, others to resistance or attenuating effect of distance.

As noted, there are many spaces and possible measures. These spaces are defined by assigning properties to the distance measure. There is really no one concept of distance suitable for all geographic and socio-economical purposes. The problem must be evaluated and then properties of the different concepts of distance measure specified.

The concept of distance as related to different spaces can be expressed in different ways: as physical, economical, sociological and psychological. In doing so, we become more aware of the total number of factors at play in creating spatial patterns and we are able to give a better and more comprehensive explanation of the facts.

The concept of distance can be understood in two principal ways. One of these, I call it ex ante, has been established through application of some standard units as unit of physical length, time, cost, opportunities. The second — ex post — is based on determining some empirical relationship between specific phenomena and then proper dimension of functional distance is derived and recognized. This concept of distance is based on observed regularities of social phenomena with no *a priori* postulates about its possible relation to any concepts of standard unit of distance.

I do not intend to discuss largely the problem of physical distance. Most often the physical distances are measured as straight-line distances (geodetic). But it does not mean that there are no questions to problem concerned. There are some non-trivial problems concerning a method of measuring the length of an empirical line or a set of lines. A good example are the works of Steinhaus (1954) and Perkal (1958). They developed epsilon neighbourhoods method to overcome the paradox of length: the more accurately an empirical line is measured the longer it gets. A paper given by Nordbeck (1964) on road net distances and the one by Nystuen (1966) on effects of boundary shape are demonstration, that such questions should not only be thought of as theoretical value but they lead to very useful empirical results.

In spite of the simplicity of the physical concept, there does appear to be some agreement that physical distance should be replaced by economic distances. As regards social and economic activities such "utiles" as cost of transportation, travel time — are more relevant measure of distance than physical distance. This view supports the argument that all location theories postulate only relative locations as one of the basic assumptions.

Isard (1960a, p. 506) and other authors suggest that economic distances might be measured also in amounts of fuel consumption in transportation, or in a number of gear shifts, sales of newspapers, or of intervening opportunities. It should be noted that Stouffer's technique for computing intervening opportunities involves the circular reasoning that Anderson (1955, p. 289) and Hägerstrand (1957, p. 121) strongly criticized.

A very aggregative concept of economic distance proposed Lachene (1965). He used the concept of "remoteness" as depending on a number of factors: physical distance, time, route capacity and residual term.

The remoteness $E_{uu'}$, separating two points u and u' measured along the network might be considered as a function:

$$E_{uu'} = e_1 D_{uu'} + e_2 T_{uu'} + \frac{e_3}{C_u - c_u} + \frac{e_4}{C_{u'} - c_{u'}} + e_{5uu'}$$

where,

$E_{uu'}$ = the physical distance between u and u';

$T_{uu'}$ = the shortest time or a weighted average necessary to go from point u to point u';

C_u; $C_{u'}$ = the total capacity of the networks joining u to u';

c_u; $c_{u'}$ = the present traffic on the networks at points u and u';

$e_{1,2,3,4}$ = weights; e_1, e_2 may be considered prices;

e_5 = residual term may include such factors as, quality of the network, relief etc.

Although the operational value of Lachene's proposal may be called in question, this concept links together the different characteristics of the network distance including the nature of possible capacities.

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Some authors call economical distances also "functional" because these distances are functions of physical distance, but the term with respect to them seems to me not adequate.

I want to pay more attention to a different concept of distance which is vaguely termed "social distance" and which is really the functional type of socio-economic distance as "ex post" construct. Such a functional type of distance is derived construct from an empirical interaction relationship based on gravity model and on the concept of finitely structured socio-economic space, that is, the space whose parts are not infinitely divisible but are composed of certain units or regions. Distance is defined by "distinguished path" which can be coordinated to socio-economic interaction.

Basing on the concept of gravity model there is a possibility to develop two ways of operational defining and computing functional distances. Attempts in this respect were done by Deutsch and Isard (1961) and Coleman (1964).

First one is based on a reversed computional procedure of gravity model which permits using relevant characteristics of population and the data on interaction to make approximation of distance termed by Deutsch and Isard (1961) as an "effective distance".

In essence the concept of effective distance may be viewed as some weighted average of many component elements interpreted as different type of distance. Mathematically the effective distance between actor categories i and j (places) is defined:

$$d_{ij} = x_{ij} \cdot w_{ij}$$

where,

x_{ij} = a vector in n dimensional space; each component of this vector measures one aspect of distance, for example the first one measures physical distance, the second one — economic distance (transport cost), the third one political distance etc.

w_{ij} = a weight vector in n dimensional space, each of its components being a weight to be applied to the corresponding elements of x_{ij}.

The proposed method of computation would permit to identificate and measure only effective distance as the average result without the determination of the basic component elements and their proper weight. Employing the simplest gravity model.

$$I_{ij} = kM_i M_j / d_{ij}$$

and then if relevant characteristics of population (M_i, M_j) and data about interaction measure e.g. transaction flows (I_{ij}) are available, as the independent variable, it is easy to determine first approximation of effective value of distance (d_{ij}), as the dependent variable. The resulting value of distance is specific for each kind of interaction.

An argument against the proposed method is the strongly deterministic character of gravity model. Partly opposite argument is that it fulfills not the role of hipotetico-empirical function, but the role of some base standard for measuring.

A much more sophisticated way of measuring functional social distance is based on the method of residues put forth by Coleman (1964). The proposed strategy is to use gravity model as a null hipothesis and then to use deviations from the predictions, consequent upon this assumption, as a measure of various functional distances between interacting actor categories (cities, regions). Statistically there is a simple way based on standardization and extraction of one factor after another from standardized data to give a set of residuals.

What is assumed, in essence, is the use of gravity model as a base line for the measurement of interaction between interacting actor categories. If we assume also that the data on spatial interaction (e.g. airline trips) between some number of cities are listed in the form of matric then the proposed analytical procedure consists of few steps.

The first step is the standardization of empirical measure of interaction e.g. the travel rate for population size in the form:

$$Y_{ij} = I_{ij} / M_i M_j$$

where,

Y_{ij} = the travel rate standardized for population size;

I_{ij} = interaction between places i and j e.g. number of travels per time period (non-directional movement);

M_i, M_j = size of population of places i and j.

In the second step this population-standardized rate is standardized for distance by multiplying by d_{ij}. This gives

$$W_{ij} = Y_{ij} \cdot d_{ij}$$

where,

W_{ij} = the travel rate between places i and j standardized both for population and distance;

d_{ij} = physical distance between places i and j.

In the third step, the W_{ij}'s are divided by the average W_{ij} taken over the whole matrix. The resulting quantity is:

$$Z_{ij} = W_{ij}/\left[\sum\sum W_{ij}/N(N\text{-}1)\right]$$

where,

Z_{ij} = the population-and-distance standardized travel rate divided by the average rate for all pairs of places in the matrix;

N = number of places (cities).

In the fourth step for each place (city) its average standardized travel rate is "factor out", that is, each entry Z_{ij} in the matrix can be divided by the two average rates Z_i and Z_j to obtain a residual value V_{ij}:

$$V_{ij} = Z_{ij}/[Z_i Z_j/N^2] .$$

Finally, the effect of physical distance can or not, be eliminated. If the variation in Z_{ij}'s with d_{ij} shows an important relationship, then the effect of physical distance in the form of the regression coefficient for distance b can be "factor out" and a new residual S_{ij} is obtained:

$$S_{ij} = V_{ij} - bd_{ij}$$

The analysis could go on in this fashion and other factors still unexamined, as political, economic or socio-psychological, which are presumed to affect this type of interaction, e.g. airplane travel, can be extracted and eliminated. The residuals which finally remain may be explained as functional social distance between interacting actor categories. The determination of the basic components of elements of such distance is also not solved but we can establish what elements were excluded.

The deviant analysis of residue distances may give a basis for a new typology of interacting groups (cities, regions). The other problem may be the question, what are the circumstances under which distances thus defined fluctuate in time.

In the contradiction to all traditional distance measures being somehow related to each other, the distinctive character of various kinds of interaction, having different operational definitions, may lead to discover the picture of the "latent" spatial structure in a broader sense of the term.

Distances defined in this manner may be called in question do they appear to have the properties which one desires of distance, otherwise, do they follow postulates of metric spaces? The problem is inherent in works on map projections and transformations. The subject of map projections practically applies only to metric spaces. That is why attention should be drawn to the question to what extent properties of the metric space may be extended into non-physical distances.

Its follows from the definition given by Blumenthal (1953, p. 15) that an abstract metric space is formed by attaching to each pair p, q of elements (points) of an abstract set a non-negative real number pq (distance), in accordance with the following agreements:

Postulate I. If $p = q$ then $pq = 0$.

Postulate II. If $p \neq q$ then $pq > 0$.

Postulate III. The number attached to an element-pair is independent of any order of elements in the pair; that is $pq = qp$.

Postulate IV. For each three elements p, q, r of set, $pq + gr \geqslant pr$.

Thus the distance in a metric space is

(a) positive definite (postulates I, II imply $pq \geqslant 0$ and $pq = 0$ if only if $p = q$),

(b) symmetric (postulate III), and

(c) satisfies the triangle inequality (postulate IV).

Distance function $d\,(a, b)$ has formally all of the properties characterizing the abstract metric space except, of course, the property of being a non-negative real number.

The analysis of different concepts of non-physical distances permits to establish to what extent they satisfy these postulates.

The first postulate is not satisfied by transportation cost-distance with terminal cost and by newspaper sales, nor by functional social distance when we agree that a mass (population) interacts upon itself.

The third postulate may be not fulfilled in the case of the cost-time and cost-distances which are sometimes non-symmetric e.g, travel on a one-way street system or a transportation uphill and downhill. As regards functional social distance it does not appear to be satisfied in the case of directional movement at indicator of interaction. Such distances are not Euclidean because of their lack of symmetry.

The fourth postulate does not appear to be satisfied be functional social distance as well as, sometimes, by cost- and time-distance. Spaces for which the triangle inequality postulate is not valid are known as semimetric spaces. Though distance in a semimetric space has been given all those properties that one thinks of as most natural for "distance" to possess, they are apparently not enough to prevent the occurrence of undesirable irregularities.

In the present stage of knowledge the conditions under which the different socio-economic spaces can appropriately be considered as different type of metric or semimetric space are difficult to determine. As a truism it may be treated the view that the ability to perform non-physical distance transformations through the abandonment of the principles of Euclidean geometry, in the recent work on map, will be very important contributions to spatial socio-economic research.

BIBLIOGRAPHY

[1] Ajo R. (1957) *New aspects of geographic and social patterns of net migration rate.* In: D. Hannerberg, T. Hägerstrand, B. Odeving, Migration in Sweden, Lund Studies in Geography, Series B, pp. 170–183.

[2] Anderson T. R. (1955) *Intermetropolitan migration: a comparison of the hypotheses of Zipf and Stouffer*, American Sociological Review, vol. 20, No. 3, pp. 287–291.
[3] Blumenthal L. M. (1953) *Theory and applications of distance geometry*, Oxford.
[4] Bunge W. (1962) *Theoretical geography*, Lund Studies in Geography, Series C, No. 1.
[5] Chojnicki Z. (1966) *Zastosowanie modeli grawitacji i potencjału w badaniach przestrzenno-ekonomicznych* (Sum. The application of gravity and potential models in spatial economic research), Warszawa.
[6] Churchman C. W. (1961) *Prediction and optimal decision*, Englewood Cliffs.
[7] Coleman J. S. (1964) *Introduction to mathematical sociology*, New York.
[8] Deutsch K. W., Isard W. (1961) *A note on a generalized concept of effective distance*, Behavioral Science, vol. 6, No. 4, pp. 308–311.
[9] Dodd S. C. (1954) *Physical dimension of social distance*, Sociology and Social Research, vol. 38, No. 5, pp. 287–292.
[10] Dziewoński K. (1962) *Theoretical problems in the development of economic regions*, Regional Science Association, Papers, vol. VIII, p. 43–54.
[11] Dziewoński K. (1965) *On integration of statistical and cartographical analysis for research purposes*, Regional Science Association, Papers, vol. XV, pp. 119–129.
[12] Friedmann J., Alonso W. (eds.) (1964) *Regional development and planning: a reader*, Cambridge Mass.
[13] Hägerstrand T. (1957) *Migration and area.* In: Migration in Sweden, Lund Studies in Geography, Series B, No. 13, pp. 27–158.
[14] Isard W. (1960) *The scope and nature regional science*, Papers and Proceedings of the Regional Science Association, vol. 6, pp. 9–34.
[15] Isard W. (1960a) *Methods of regional analysis: an introduction to regional science*, New York.
[16] Jammer M. (1960) *Concepts of space*, New York.
[17] Lachene R. (1965) *Contribution a l'analyse de l'espace èconomique*, Metra, No. 6.
[18] Nordbeck S. (1964) *Computing distances in roads nets*, Regional Science Association, Papers, vol. XII, pp. 207–220.
[19] Nystuen J. D. (1963) *Identification fundamental spatial concepts*, Papers of the Michigan Academy of Science, Arts and Letters, vol. 33, pp. 373–384.
[20] Nystuen J. D. (1966) *Effects of boundary shape and the concept of local convexity*, Michigan Inter University Community of Mathematical Geographers, Discussion Papers, No. 10.
[21] Olsson G. (1965) *Distance and human interaction, a review and bibliography*, Philadelphia.
[22] Olsson G. (1965a) *Distance and human interaction. A migration study*, Reprint from Geografiska Annaler, vol. 47, Series B.
[23] Perkal J. (1958) *Próba obiektywnej generalizacji* (An attempt of objective generalization), Geodezja i Kartografia, vol. VII, No. 2, pp. 130–142.
[24] Perroux F. (1950) *Economic space: theory and applications*, Quarterly Journal of Economics, vol. 64, No. 1, pp. 89–104.
[25] Sorre M. (1957) *Recontres de la géographie et de la sociologie*, Paris.
[26] Steinhaus H. (1954) *Length, shape and area.* Colloqium Mathematicum III, Wrocław, pp. 1–13.
[27] Tobler W. (1962) *A classification of map projection*, Annals of the Association of American Geographers, vol. 52, No. 2, pp. 167–175.
[28] Tobler W. (1963) *Geographical area and map projections*, The Geographical Review, vol. 53, No. 1, pp. 59–78.
[29] Watson J. W. (1955) *Geography — a discipline in distance*, The Scottish Geographical Magazine, vol. 71, No. 1, pp. 1–13.
[30] Webber M. M. (1964) *Culture, territoriality, and the elastic mile*, Regional Science Association, Papers, vol. 13, pp. 59–69.
[31] Znaniecki F. (1938) *Socjologiczne podstawy ekologii ludzkiej* (Sociological foundations of human ecology) Ruch Prawniczy, Ekonomiczny i Socjologiczny, vol. 18, pp. 89–119.