Representations of Development Concentration in Models Based on the Idea of Intervening Opportunities

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The process of site planning uses mathematical models which illustrate real processes. It means a standardized record of actions, which reflect the conditions in accord with general regularities, so that they can be used to regulate, manage, and control the course of processes. Examples of the genuine processes structure are necessarily connected with the notion of various infrastructure types concentration, which corresponds to various types of activity arranged over a particular area. This fact is proved correct by numerous models illustrating the processes of setting up concentration within an urbanized area, used in practice as a tool for supporting the process of planning. The following paper presents examples of concentration obtained as a result of modelling the reallocation balance patterns. Key words: site development, modeling od processes, intervening opportunity model.

The modelling of occurences happening within a developed area has a long history and constitutes a basic research method. The use of the method nowadays is connected with system approach, which means defining objects identified over a space as complex systems. It it possible to define the systems by means of two basic categories: structure (elements and relations that link them), and behaviour (reaction to stimuli). Spatial structure means actual, located by a particular manner, sets of economic or social units along with various mutual relations. The elements of a spatial system can be regarded in terms of their spatial qualities, e.g. location in space and their relation with other elements. They can also be viewed as generators of the processes leading to the creation of new examples of site development.

The abovementioned system of units depends on the geographical (in other words natural) environment, and anthropogenic units located within, which represent man-made infrastructure. Infrastructure development brings new forms of activity which force the infrastructure to adapt to the changing factors. At the same time, the relations between the infrastructure and the new forms of development are of feedback character.

As for the structure modelling, the model is created in a descriptive manner (verbal model) often supplemented with pictorial material (scale models, maps, visuals), however with possible behaviour types mathematical models apply, which impose the selection of measurable features presented in a model in their formalized shape. These models, being simplified depictions of the reality, are based on particular features of actual systems. The selection of the features mentioned of an actual system is mainly dependent on the aim of the conducted research.

With grand spatial settlement systems the main idea is to recognize them better, and above all to identify the mechanisms influencing the shape of those systems.

The process of spatial planning uses mathematical models which illustrate real processes by means of presenting in a model the dependencies between system elements in the forms of analytical function, and more often in the form of the probability layout of the variable which distinguishes the process. It means a formal record of mechanisms which reflect states in accordance with general regularities, so that after identifying their detailed influence on the general image, they can be applied to regulate, manage, and control the course of processes. In order to do that numerical modelling is most often used [2, 3, 8, 11, 12, 13, 14].

Such models are called simulative because the image of the target state is acquired by means of consecutive approximations (iterations). The process is continued until a balance of the system modelled is reached; in other words until a certain ideal standard has been achieved, which can constitute an indicator regarding the necessary changes, with existing factors considered.

Simulation techniques are particularly useful in those areas where analytical determination of a solution would be much time consuming, and sometimes impossible; which is a common occurrence in complex systems.

The following paper presents patterns received by means of modelling transit with the use of indirect capabilities model.

1. PHYSICAL SYSTEM AND ITS MATHEMATICAL MODEL

In the theory of urban planning the basic elements of settlement system are complex spatial objects which can be defined in terms of numerous features. In order to do this, certain description techniques are used which are in accordance with a general theory of systems and systems research [7]. In the theory of systems, a notion of *relations* linking *elements* of complex structures is used. Those relations prove the existence of mutual dependencies between the elements of a system and its connection to the environment. The systems defined within a developed area are open systems, which means they can interact with the environment in a free fashion. The research method which is applied, in case of complex spatial systems, is most often modelling.

Systematic approach is similar to the definition of urbanization processes formulated by T. Zipser [14]. According to the definition, urbanization processes are such processes which transform the initial development state into a state which is correspondent to the condition where there exists a certain probability of occurrence of contacts and balance. The contacts mentioned account for multiple types of relations between the elements of a spatial system. A pair of elements which interact are called 'source' and 'target' of a contact.

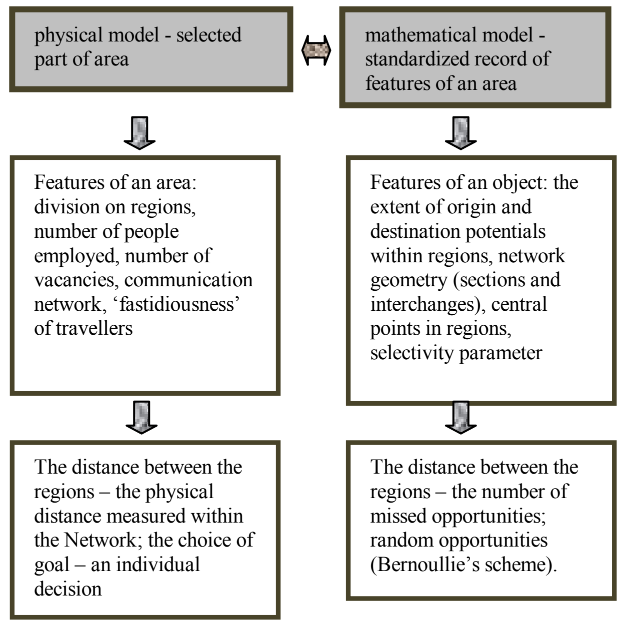

Figure 1. physical model of an area and its corresponding mathematical model. Source: own analysis.

The fashioning of a layout of contacts is influenced by a needs model established in a particular civilization; at the same time the structure of a spatial system should be subordinated to the structure of inhabitants' needs.

The state of balance is correspondent to the 'standard' situation, where the number of contacts and targets offered by a particular spatial system is in agreement.

Transformations of the structure of spatial systems are usually due to the following phenomena:

- modification of needs model
- change in potential contacts range
- change in the number of elements of a layout

The last point means a change in the balance conditions. In certain situations new contacts are generated, also negative[1].

1 Negative contacts, in other words conflicts, are such contacts whose presence has a negative influence on existing forms of development and over a community in a particular part of an area (e.g. environmental pollution due to the introduction of a bothersome industrial function in a direct vicinity of a residential area).

In the course of the development of urbanization, there occurred processes which repeatedly led to the transformation in the structure of spatial systems. In the history of urban development we find numerous examples which prove that there is no target state after which a city development is striving. Structure transformations caused by consecutive changes (both positive and negative) create – after temporary disturbances of the balance, a transition to a next stage of development and new balance.

The examples of the structure of urban systems as well as greater settlement systems are inherent to the phenomenon of concentration of various types of infrastructure responding to actions, that is different forms of activity within a city area. The fact is confirmed by numerous models illustrating the processes of concentration inception over an urbanized area (Christaller's model, gravitative models, models based on the idea of indirect probabilities, or a model suggested by Prigogin, which describes the probable development of urbanization). Although all the models mentioned above reconstruct the same processes of concentration inception, they reflect in different ways the actions between the elements of a spatial system, which directly influences the character of target states.

In Christaller's model [6] we deal with a symmetrical example of site development, which in reality does not have a chance to last over a longer period of time. A good example of urbanization process which contravenes Christaller's model is the result of a computer modelling presented by I. Prigogin [10]. The model used, which started with homogenous distribution of level 1 activities (similarly to Christaller's model), called rural system, presents a probable character of the course of urbanization. Conducted computer simulations indicate that even with a homogenous initial distribution, the very act of random factors such as place and time of starting various economic undertakings, causes a collapse in the symmetry and the occurrence of activity zones of an intense concentration, whereas in other areas we encounter a decline of economic activity and a decrease in the number of population. The same tendecy is confirmed by numerous applications of models based on the idea of intervening opportunities, which have been developed for many years under [1, 2, 3, 12, 13, 14].

The model is a simplified representation created in order to comprehend the workings of substantial system. Models developed under T. Zipser are quantitative, which means they use particular measurable features and are of probabilistic character. This means that the target state can be reached with the highest probability. In general, modelling is basically searching for features and relations within a system significant for a particular target. Reconstructing real situations in a model is performed through simulation, which means transforming input data in a way that allows a system to function in altered conditions, thereby facilitating the capture of influences and conducts, whose observation would be impossible in the case of an actual system.

2. INTERVENING OPPORTUNITY MODEL

The attempts of model representation of contacts over an area in actual systems, i.e. interactions or movement between the elements of a system, are based on two theories which differ as regards space research. The models based on them are applied to fashion most interactions between the elements of spatial systems (cities, regions, countries). The deliberations presented below concern models based on one of these theories called the *idea of intervening opportunity*.

A settlement system is developed by the working of a set of contacts between its elements. If we want to recognize the structure of a system we need to analyze a system of contacts which bind individual elements. Contacts analysis is associated with determining so called contacting rules which provide information on the object and the subject of a contact, the place where a contact starts and ends, as well as the type of infrastructure which will allow a certain class of contacts to exist.

Intervening opportunities model allows to calculate the number of travels between each pair of regions into which every analyzed area is divided into (fig. 1). The extent of the travelling flux between the starting and the target area is influenced by both the number of journeys initiated and the dimension of the target set, as well as so called *intervening opportunities* which are circumstances near the source than the target region.

A parameter of the model, called *travel selectivity*, represents the probability of accepting a potential target, which is regarded as a feature of the level of civilisation for a particular area. The higher the needs specialization (e.g. professional qualifications), the smaller the probability of satisfying a particular demand at any point of an area [9].

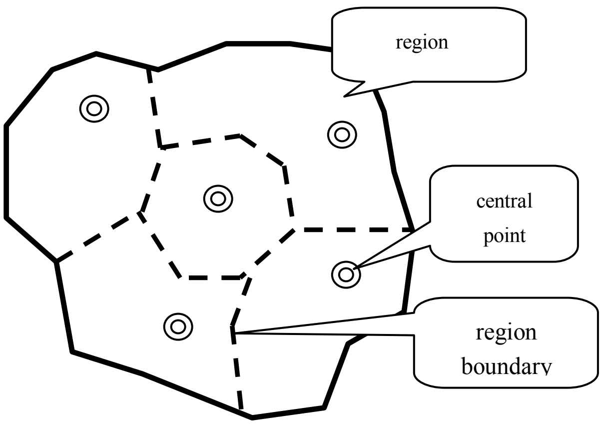

Figure 2. Regionalization of an area
Source: own analysis

This means that the chance of satisfying a need in a direct proximity to its source is low. The idea of intervening opportunities, formulated by S. Stouffer, refers to a situation where we analyze the contacts in the form of a flow of people between particular places within the developed area. Stouffer's hypothesis [4] assumes that the number of travels between the source region (starting point) and a selected target region (destination point) is reliant not only on the number of passages initiated in the source region and the destination, but also on the quantity of intervening opportunities located between the considered regions. It is these targets which constitute an environment where the initiated passages may stop, and in effect only a fraction of the total number of travels will reach the target region.

In 1959-60, M. Schneider developed Stouffer's idea by designing a model which applies the probability calculus method.

The model based on the above assumptions is probabilistic and characterizes the distribution of travels initiated in a particular source and aiming for various targets located within a particular space. What we have here is Bernoullie's trial sequence, where a success is marked by a completion of a journey, whereas a failure is continuing the travel which means passing the target. In the final functional version of the model, the probability of a success (initially characterized for a discrete sphere of events) has been substituted with acceptance probability frequency (in a continual sphere of events).

The notation of the model is:

$$T_{ij} = z_i * P_{ij} \text{ for i,j = 1, …,n.} \quad (1)$$

where: z_i – the value of the original potential in a region numbered 'i'

P_{ij} – the probability that a journey starting in region 'i' is terminated in the zone containing the target numbered 'j'.

The final formula takes the following form:

$$T_{ij} = z_i * [e^{-sa} - e^{-s(a+a_j)}] \quad (2)$$

where:
e –base of natural logarithm,
s – travel selectivity
a – number of frequencies closer to the source than the zone numbered 'j' which contains target region
a_j – number of frequencies in zone'j'

The notation in square brackets is the difference in the value of distribution of exponential function. After appropriate transformations of the notation we receive a formula which allows us to determine the extent of the set of occasions which guarantees that with a particular selectivity rate ***s***, the expected percentage of demands will be satisfied. We receive then:

$$a = \frac{\ln(\frac{1}{R})}{s} \quad (3)$$

where: *a* means the number of opportunities required, with selectivity equal to *s*, over the analyzed area, so that only a fraction of demands (passages) - equal to R – is not satisfied. Similarly, when we know the rate of the set of occasions, it is possible to determine the level of selectivity which will allow satisfying an appropriately high percentage of demands. The selectivity formula applies:

$$s = \frac{\ln(1/R)}{a} \qquad (4)$$

A distinctive feature of the model presented, constituting a method of researching interregional traffic interchange, is the occurrence of the surplus of travels terminated in some regions with a simultaneous movement scarcity in other areas. The solution is reached by means of iterative method; assuming conclusive a state which is correspondent to a situation where system balance is ensured at a possibly highest degree. The balance is regarded as a state when the number of demands expected to be satisfied within a particular area, with certain selectivity, will not considerably differ from the number of existing opportunities. As a result of modeling we receive a representation of concentration correspondent to the state of balance.

The fundamental algorithm of the model, depending on the purpose of modeling and on the influence of additional factors, can assume various forms. Multiple applications of different types of the model of *intervening opportunuties* demonstrate a significant influence of the sort of communication network on the form of the solution; with other conditions established (invariable value of the selectivity parameter and determined volume of traffic potentials). An important factor which influences the type of concentration within a system is so called accessibility of target regions, which is their location inside a network.

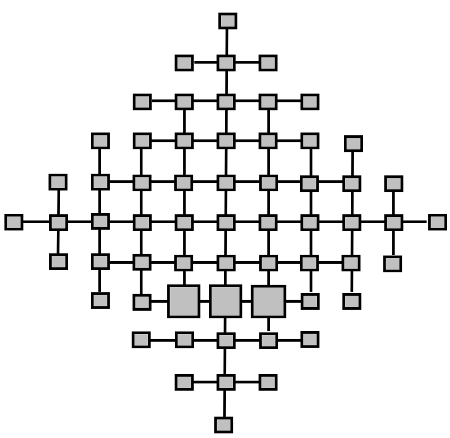

Figure 3. Communication network (notional) type ‘E’: initial state – asymmetric localization of concentration. Source: [15].

The representation of a balance state received through the intervening opportunities model is development concentration in certain points of a system, while in others we observe a decline. Despite assuming an identical value of the selectivity parameter for all regions of the analyzed area and similar rates of origin and destination potentials, thus accepting uniform distribution of traffic possibilities as an initial state, after a series of modeling we receive an asymmetric image of development, which means a concentration system of different intensity in various points of a particular area.

The case presented in figure 3 indicates that when starting with uniform distribution of potentials and the applying of asymmetry in three selected regions located in the third zone from the center of the system, as a result of modeling we receive a multi centric system (fig. 4); at the same time regions of highest potential at the start of the modeling process will maintain advantage, concentrating most activeness.

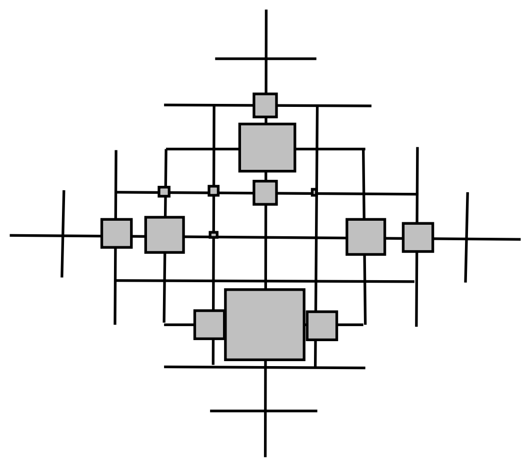

Figure 4. Communication network type ’E’: State of balance achieved through *general relocation*. Source [15].

The following three figures picture the results of modeling by means of the *target relocation*. Starting from a uniform distribution of potentials, concentration types were received which were then divided into three groups: centers of several dozen units – smallest circles, several hundred units – medium size circles, and the greatest centers of several thousand units – biggest circles. The figures present successive concentration: a) – 5th iteration, b) – 30th iteration, and c) – 100th iteration. As the system approaches the state of balance, it is easy to notice a distinct concentration shift from the centre outwards. At the same time regions marked by smallest circles experience a decline in concentration process.

The situation changes in the next three figures presenting successive stages of reaching a state of balance during the modeling of the same system with *general relocation model*. In this case the concentration of development proceeds faster within regions located in the centre of a system. The remaining regions 'give away' development for the central zone. The example given reveals a fundamental difference between the two versions of models. In the *target relocation model* (with preliminary assumptions: the extent of the source and target potentials, the value of the selectivity parameter) we receive concentrations in several distance zones, arranged concentrically against the system centre. There are no considerable concentrations in the centre itself (fig. 5).

The *general relocation model* creates more promptly grand concentration of activity in the centre of a system or around it, with a simultaneous development shift from the remaining areas. The situation often causes the effect of development 'sweep-away' from those regions (fig. 6).

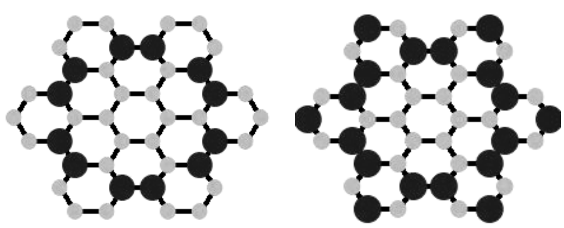

Figure 5. Communication network type 'D' – modeling by means of the *target relocation model*. From the left above: result after 5th and 30th iteration. Below: result after 100th iteration.
Source: own analysis.

Concentration phenomena are the most distinctive representation of site development. They are most often analyzed and defined in the form of models and regularities. The examples of such models as well as various definitions of occurring regularities are e.g. Clark's rule [5], Newling's model, dimension and sequentially rule (called Zipf's rule). There are also multiple methods for concentration measurement e.g. Lorentz's curve, or Steinhaus's habitation rate. The models and rates mentioned can be applied in modeling the processes of urbanization as instruments which facilitate the comparison of the results of modeling with actual situations [14]. Within a developed area it is possible to distinguish three types of concentration formation: coincident, consequent, and cooperative.

Coincident concentration occurs when certain places within a specific area become particularly desirable, irrespective of each other, for a greater number of prospective buyers.

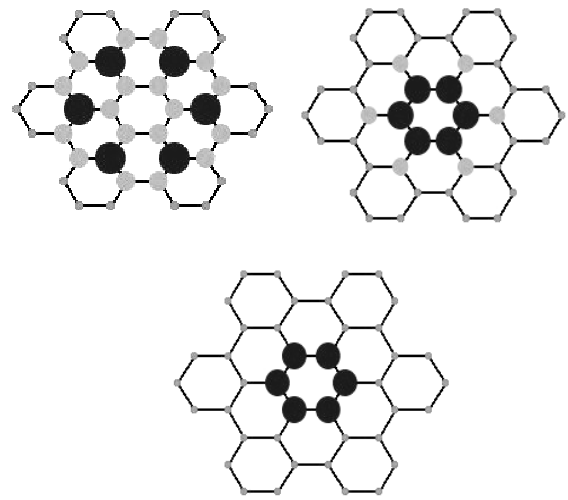

Figure 6. Communication network type 'D' – modeling by means of the *general relocation model*. From the left above: result after 10th, 30th, and 50th iteration.
Source: own analysis.

It means that the value of the place itself attracts them. Concentration in this case is the result of coincidental motivation as well as mutual competition. This type is simulated by means of relocation models. An example of coincident concentration can be the localization of shops, offices and government institutions in the central parts of a city, i.e. areas of the highest accessibility.

Consequent type occurs when the concentration is a result of a certain form of development which attracts other forms. This type is illustrated by the emergence of chapels and churches, as well as pubs, and workshops in a direct vicinity of market places.

Cooperative concentration occurs when there is a direct necessity for contact between the assembling units of development. The example of this type of concentration is the co-occurrence of trade organizations and banks as well as large industrial plants, and an appropriate communication and energy infrastructure. The last type of concentration discussed can establish a very durable and change resistant formation in areas of urban centers.

Substantial networks are generally a cluster of various types of theoretical systems. Tendencies of standard notional networks. Assuming a preliminary distribution of the elements of development which, following the model of *intervening opportunities* and a determined system of accessibility and selectivity of needs generates transfer, we receive a new distribution of activity which constitutes a point of reference for alteration to the existing development.

The use of modeling in order to acquire substantial representations of concentration has, in many cases, led to the genuine reconstruction of existing (also historical) structures [13].

The application of the analyzed models in the course of site development constitutes a useful instrument to verify the 'correctness' of the location of various forms of urban development. The models for the distribution of development units received through modeling form a basis for comparison with the actual state, and determine the course of required changes.

BIBLIOGRAPHY

[1] Bagiński E., Litwińska E., Zipser T., *Próby symulacji modelowej rozkładu przestrzennego ruchu turystycznego w Polsce,* Wrocław 1995.

[2] Chądzyńska E., Zipser T., *Iteracyjne i analityczne metody modelowania koncentracji w obszarach uprzemysłowionych w oparciu o relację dom – praca.* Referat na II Polsko – Austriacką konferencję, Wrocław 1984.

[3] Chądzyńska E., *Analityczne metody wyznaczania równowagi kontaktów oparte na modelu pośrednich możliwości.* Praca doktorska, Wrocław 1985.

[4] Chicago Area Transportation Study. Final Report, Part 2, Chicago 1960.

[5] Clark C., *Urban Population Densities,* Bulletin de Institute Internationale de Statistique, 1958, vol.36.

[6] Christaller W., *Ośrodki centralne w południowych Niemczech,* PZLG, 1963.

[7] Dembowska Z., *Planowanie przestrzenne w ujęciu systemowym, PWN, Warszawa 1978.*

[8] Chorley R.J., Hagett P. (ed.), *Socio-Economic Models in Geography,* London 1968.

[9] Głogowski K., *Badania nad strukturą parametru selektywności dojazdów do pracy,* Politechnika Wrocławska (praca doktorska), Wrocław 1978.

[10] Prigogine I., Stengers I., *Z chaosu ku porządkow,* Warszawa 1970.

[11] Wilson A. G., *Entropy In Urban and Regional Modelling,* London 1970.

[12] Zipser T., *Algorytmy zmodyfikowanego modelu konkurujących szans a) przesunięcie celów b) Przesunięcie ogólne*, Zakład Urbanizacji i Planowania Przestrzennego Politechniki Wrocławskiej (maszynopis powielony), 1969.

[13] Zipser T., *Modelowanie komputerowe w badaniach zjawisk koncentracji w systemie osadniczym 1963 – 1994,* w: E. Bagiński (red.) *Zarys metod i technik badawczych w planowaniu przestrzennym,* Wrocław 1996.

[14] Zipser T., Sławski J., *Modele procesów urbanizacji. Teoria i jej wykorzystanie w praktyce planowania,* Studia tom XCVII, PWE, Warszawa 1988.

[15] Zipser T. i zespół, *analiza i ocena alternatywnych modeli docelowych systemu osadniczego, Etap III,* raport Instytutu Architektury Urbanistyki Politechniki Wrocławskiej (maszynopis powielony), Wrocław 1980.