THE BIRTH OF POLYNUCLEATED METROPOLITAN LANDSCAPE

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Abstract
Along the history of urban formations the polynucleated urban form has been a very scarce phenomenon. (Batty, 2001) During this on-going era of metropolitanization this phenomenal issue is about to change. The fractal growth of urban outskirts under development is very different from the previous era of the fordist urbanization, but still the urban footprint seems to follow similar scaling laws characteristic to historical process. (Humpert et al, 2002) The aim of this paper is to demonstrate that intrinsic urban properties derived from the measures of integral accessibility (Ingram, 1971) and spatial connectivity (Hillier, 1996) produce urban formations that are equally well-defined as the laws of extrinsic measures. The network theory based method for quantifying generic accessibility is developed in the author’s doctoral research and proven highly relevant.

The series of historical maps of Helsinki is used to define the accessibility levels of earlier developmental stages of a metropolitan area. These temporally sequential development phases are used to show how the non-linear phenomenon of growing accessibility neighbourhoods is a natural cause for new kind of urban nodes in growing metropolitan scale structure. It is argued that the market locations as well as the other major urban facilities are largely dependent on this fundamental principle of accessibility originally formalized in the seminal work of W.G. Hansen (1959).

It is only this increased mobility within the metropolitan region that has made the birth of new urban formations possible. The most remarkable feature of an intrinsic accessibility-based growth is that it generally doesn’t require any seed for the birth of a new urban node. The polynucleated form seems to be generated as a self-organizing process of an accessibility potential taken advantage of. This also holds true with intuition as well as empirical research of urban formations where the relevant preliminary phase is hardly ever found. At the beginning there is only accessibility.

Keywords
accessibility, polycentric urban form, time-geography, travel-time budget, potential path space

Introduction

The concept of accessibility is probably the most used name for indices of measuring or quantifying the intrinsic properties of urban agglomeration, yet the concept itself is not in anyway rigorously defined. As a matter of fact, the intuitive intelligent layman perspective has dominated the discussion, and the concept itself is becoming obsolete. Similarly the original idea of a polynucleated urban formation introduced by Edward L. Ullman and Chauncy D. Harris some half a century ago is at the edge of disappearing into the un-analytical small-talk of an average cocktail party. The problem with everyday use of multi-centred urban structures is little different than that of accessibility. The problem isn’t in the number of centres as such, but instead in the concept of centre itself. The traditional definition of centre as CBD (Central Business District) is made understandable through historical determinism only. The concept itself doesn’t contain any hint of its origin. The best description of the formation of centres is explained that they are caused by a seed of some kind that in turn attracts other central activity. When speaking of polynucleic formations the original problem concerning the birth of a centre arises, since hardly ever any previous function that could be seriously accepted as a seed for agglomeration is found. The aim of this paper is to give an adequate explanation for the polynucleated cityscape by redefining the centrality as a property of evolving accessibility.
Accessibility formalizations

As mentioned earlier there is no standard measure for accessibility. It is obvious that all the locations within an urban area need to have access of some kind and thus have a property that can be termed accessible. This is about as much as we can say there is in common with various indices measuring this profound feature. All additional questions (who, how, why, when etc.) for surrounding the basic idea lead into the ever greater knowledge of details, but also at the same time into the loss of generality. For modelling purposes there are several formalizations, but two separate strands seem to be the most useful ones for further development.

The first group of these measures is a set of indices that could be termed integral accessibility. The integral measures are the most traditional type of accessibility measures that can be summarized as concentrating on evaluation of spatial (usually zonal) properties according to the impedance of movement. Competing locations around each site are creating potential fields that characterize the locational status of it. Walter Hansen’s (1959) formulation for accessibility was the starting point for these measures and methodology has been largely adopted into the large-scale urban modelling. The spatial distribution modelling as well as its ancestor the gravity modelling is rooted heavily in this tradition. The other established branch of urban models, the discrete choice models that are based on economic random utility theory, can also be grouped under this topic as depending completely on integral properties of pre-evaluated spatial conditions. The previous spatial interaction modelling has its explanation in entropy (Wilson, 1967) and can be understood as a field of potential for interaction. This work of several generations is concluded in the family of Spatial Interaction Models (SIM) by Alan Wilson (1971) and as an ultimate generalization in the “General Theory of Movement” by William Alonso (1978). The discrete choice models in turn are explained on the bases of distribution of decision rules in population and thus the modelling result may be understood as the probability for interaction. The work on theoretical foundations of multinomial logit and theory of discrete choice from mathematical psychology brought Daniel McFadden a Nobel Prize in economics in year 2000. (McFadden, 2001) Technically speaking the difference between these two modelling tradition is merely in the type of distribution that is assumed to exist in urban structure. Despite the differences in explanations both SIM as well as logit models are similar in terms of accessibility, SIMs based on lognormal and Yule distributions (Berry, 1964) and the logit model on Gumbel distribution.

Several attempts to improve the results by moving towards more disaggregated data, reducing the potential destinations, seeking for more suitable distance decay functions and so on. The second group of formalizations of accessibility that goes beyond these minor adjustments are the time-space measures. The all have their origin in Torsten Hägerstrand’s far sighted paper (1970) that started a new branch in urban geography sometimes referred as time-geography. The approach he suggested was actually to turn a regional or mass probabilistic behavioural point of view into an individual based one. Hägerstrand suggested mapping the movement of individual people according to their daily routines and thus collecting individual accessibility islands that can be tremendously different according to the mode of movement. These potential accessibility areas, determined by individual time use, he called daily prisms. According to the shapes created in the diagram of time available, and the corresponding spatial extension of movement. This individual accessibility prism was later called Potential Path Spaces (PPS) and the area covered Potential Path Area (PPA) accordingly. (Lenntorp 1976, Miller 1991) It is important to realise how different these PPA are if compared in terms of extension, for example the area potentially covered by pedestrian or motorized transportation. An additional regularity for the time geography was later suggested by Yacov Zahavi (1974) when he suggested that the time component on everyday personal mobility remains near constant.

Pirie (1979) has listed the general assumptions behind various accessibility measures that at first sight seem rather different from each other. Pirie defined two kinds of assumptions that are actually very similar to each other. These are the destination assumption and the origin assumption. Usually the assumption concerning the destination is that either all nodes are possible destinations (or in advanced case only subset of them). The presupposition related to the origin is that origin of all trips is known. Traffic planners have done major job trying to resolve the problem of trip chaining to avoid the caveats of technocracy and not to fall into brutal division between home-based and work-based trips. Yet the trip distribution within various PPA is handled only statistically based on interviews done in test area. In integral measures of accessibility both above assumptions have severe limitations if we use them on predicting the level of accessibility in the future state of time. That is because the amount of origins and potential destinations must be defined outside the model. The original rhetoric question of W. G. Hansen when he first time formalized the concept of accessibility was “How accessibility shapes land use”. I have a feeling that under previously mentioned assumptions we fail to answer this important question. We try to find an answer on this in our case study of Helsinki metropolitan area.
The evolution of road network in Helsinki Metropolitan area.
The pictures in previous page show the development of the Helsinki metropolitan area during past 70 years. From the first picture from mid 1930’s we realise the peninsular location of downtown Helsinki. The only significant new radial road connection has been realized towards the west. Mid 50’s picture is characterized by all radial connections that were necessary to fill the requirements of motorized transportation. From the last picture we recognize the current state of the metropolitan area with the nearly all planned ring road connections completed. The study area shown in the above pictures is used in following analyses consists of approximately 10000 road segments in year 1935, 15000 road segments in year 1955 and 26000 road segments in year 2000. It is easy to see the overall change in landscape during this period of time and it is almost as obvious that no seeds from earlier phases of development have determined the current state of metropolitan form. For the starting point of analysis we take the hypothesis of W.G. Hansen and believe that the changes in accessibility level serve as an important factor in understanding the changes in land-use patterns. This means that we accept the land-use change as a process that contains important features of self-organization phenomenon. Thus every planning action taken to improve the existing conditions of mobility has a potential side effect of increasing the rate and intensity of the development in areas that benefit from the changes in the intensity of interaction possibilities. Lets take closer look at this possible mechanism.

Regularities of urban change

In 1933 Charles C. Colby made an extensive literary survey to understand the development and driving forces of the metropolitan growth phenomenon. (Colby 1933) Colby recognized the evolution process that involves modification of long-established functions as well as addition of new functions. He defined two set of forces that stand out prominently. First of these are centripetal forces which “impel functions to migrate from the central zone of a city towards, or actually beyond, its periphery” and eventually “make that zone the center of gravity for entire urbanized area”. The second group, centrifugal forces, are “made up of combination of uprooting impulses in the central zone and attractive qualities of the periphery”. (ibid) Paul Krugman has recently used same characteristics very successfully. (Krugman 1996, p.76) The edge city model he describes is an attempt to explain polycentric urban structure in as minimalistic a way as possible by using interdependent location decisions of businesses. He too uses centripetal and centrifugal properties of businesses as counterbalancing forces to create spatial patterns. Interestingly though he creates the interacting model agents with property of willingness or unwillingness to cluster with other agents. The important difference with Colby definition is that the basic assumption behind the model is that there is no difference among the locations, but the desirability of location is determined by distribution of businesses themselves. The centrality and the names of balancing forces came into the picture only through the scheme that is set up for modelling to begin. With this extremely simplified model Krugman is able to demonstrate important features and oddities of urban formations such as the so called agglomeration shadow of different sized competing centres, which thus can be explained merely on bases of two distinctive properties of business agents. What still puzzle us is how the centrifugal agents choose their location and how the centres are formed in the first place?

The concepts of centripetality and centrifugality are often used terms that inaccurately describe and fall into the trap of circular causation. The basic definition of featureless plain with centrality created by agents is actually very close to the popular definition of CBD. Murphy and Vance took the existing downtown location for the starting point and defined the delimiting properties of CBD on bases of existing functions (Murphy & Vance 1954). If we in turn define the action taken by the agents on bases the same centrality we are looking for trouble. Eventually this might lead into a very unpleasant analysis. For example the analysis of the locational choices of various business sectors in Helsinki metropolitan area suggests that retailing has recently turned into a centrifugal urban function. (Laakso & Loikkanen 2004) Even though it is understandable that a certain type of retailing is vanishing more and more from the CBD (and the same phenomenon is recognized at certain degree from relocations of the traditionally CBD seeking office space), the centrifugal explanation must be wrong. Both of these are functions that typically benefit from the central location, so the above must be caused by ill-defined centrality concept itself. I feel that these Krugman’s clever distinctions of business behavioural tendencies should be more properly called “agglomerating” and “degglomerating” forces just as Robert Haig called them seven years before the Colby formulation. (Haig 1926)

If we accept the demand for centrality for retailing, we must ask what kind of centrality exists in locations typical to for example in new post-modern working-shopping clusters at the highway intersections. By returning back to Hansen’s paper, we realize certain patterns of individual travel behaviour. The amount of interaction
between locations is defined in Hansen’s formula as a negative exponential function, in which the absolute value of exponent varies according to the trip purpose. Hansen concludes the earlier results of gravity modelling and sets the exponent value for work trip into 0.9 which resembles the longest distances people are willing to travel. The amount of interaction for other purposes varies from 1.1 of social trips, 2.0 of shopping trips and so forth. For interurban movement exponents were found to be between 2.2 of work trips and 3.0 of shopping trips. (Hansen 1959) The latter result is lined up with the results of other research reports. (See for example Huff 1964, Voorhees 1955)

![Lognormal plot of interaction probability against separating distance with various trip purposes. Source: Isard 1960](image)

It is easy to see the usage of previously introduced PPS approach as a tool for estimating the inequality of individual mobility or for calibrating transportation models according to the more precise knowledge if only proper data is available. By turning previous travel behavioural patterns into the terminology of time-space accessibility we can make some general conclusions. First of all the individual willingness to make a certain trip will create different sizes of a PPA according to trip purpose. Following the narration of Paul Krugman, the interdependent businesses may be considered as agents free to move around urbanised area seeking for more desirable location. This leads into the second conclusion. *Ceteris paribus*, businesses tend to find location where the overlapping of their client, workers and other interaction counterparts can satisfy their individual PPA demands. This in turn leads to further notion that different acceptance criteria of furniture retailing and movie rental store clients will lead into different sense of centrality. As a result of these brief conclusions we are combining these different approaches of accessibility in following section and try to come up with a different kind if integral measure created by internal properties of PPAs.

**Generic accessibility**

The advances in GIS technology have provided us tools that were hardly imaginable a decade or so ago. Today’s technology gives us possibilities that it past times lead unnecessary reduction of ideas and data aggregation only due to the lack of computation power. To fill the basic requirements concerning the assumptions of origin and destination in previously introduced street/road network, and not to fall caveats of them, leads into a heavy
calculation. That is, if data is required to be completely disaggregated. A simple shortest path routing problem between all locations of present day road network requires some 17.5 trillion \((17.5 \times 10^{12})\) calculations with algorithm of \(n^3\) time complexity. This is the direction we are taking and it is not a minor task even with tools of present day computational performance.

It is shown by author that due to some regularities of flow network it is possible to lower the computational task significantly up to time complexity of \(n^2\). (Joutsiniemi 2003b) This can be achieved by performing the calculation on binary step bases which doesn’t significantly change the result since the link length and speed limit ratio remains adequately constant. This in turn reduces the overall calculation time into the operationable level. Under these circumstances for example the PPA with extension of 60 logical links roughly resembles 15 min PPS in an uncongested road network. The centrality or the integration of each PPA may be represented as a mean depth value that characterises each sub network. The analysis method is discussed in greater detail in series of papers by author. (Joutsiniemi 2002, 2003a-c) The method used is from its operational manoeuvres similar to the configurational approach used in space syntax circles with different metric properties caused by underlying network structure. (See Hillier 1996)

The following pages show the evolution of highly accessible areas during the past 70 years. The first set of pictures show the changes in the integration of 60 links neighbourhoods, second set in 30 links neighbourhoods and the third set in 10 links neighbourhoods. The most profound change between different periods of time and different PPA is that the addition of ring road connections have separated the different sized accessibility centres from each other and the locational benefits of the existing CBD area have confronted the rise of new nodes at the fringe of metropolitan area. Equivalent results with different explanation bases concerning the impact of ring road construction into the metropolitan land-use can be found from large scale space syntax analyses (Romppanen 2000, Van Nes 2002).

**Concluding remarks**

By understanding the centrality as ease of access we find significant explanations for on-going urban changes. The first set pictures in following page represent the PPA that is adequately easy to access by private car, but at the edge of accessibility for other modes of transportation. This means simply that activities that rely on PPA of this size, traditionally including working trips, manufacturing and logistic activities among others serve as potential pioneering land-use that eventually draw other activities along. The major change has gone through between 1955 and 2000 when several off-CBD connections have been introduced. Despite the on-going process of keeping up the accessibility level in CBD via heavy public transport investments and additional parking spaces to counter congestion problems, new types of alternatives have emerge. These alternatives have also been taken advantage off. The small scale improvements in urban network connectivity have also gradually followed the large scale improvements and easily accessible PPAs into the areas that earlier had a status of hinterland. From these pictures of evolving accessibility it is easy to draw the conclusion that not only the size of metropolitan scale flow network, but essentially the shape of it determines the locations where different sized well integrated PPAs create the fertile ground for diverse centre formation.
Top 30% integration isochrones of 15 minute potential path area (PPA).
Top 30% integration isochrones of 7½ minute potential path area (PPA).
Top 30% integration isochrones of 2½ minute potential path area (PPA).
References


