Designing for Pedestrians:

A configurative approach to neighborhood planning and design, promoting pedestrian mobility, using an interactive computational design method for 'polycentric distribution of built space' according to walkability, attractions and topographic features

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Pedestrian Accessibility, Polycentric Distribution, Neighborhood Design, Walkability Analysis, Computational Design, Spatial Configuration

Introduction

In certain urban development projects we may want to increase the built space density of an existing neighborhood to make use of already existing infrastructure and avoid urban sprawl. In such a case a number of new inhabitants are to be housed in the neighborhood and that means an amount of built space is to be added over existing urban lots. We could consider a similar situation for a new town design as well. In any case, an important question would be: how to distribute this amount of built space? In other words, how to configure the neighborhood in terms of massing? A general question would be: how to design/transform a neighborhood, promoting pedestrian mobility and distribute built space across the street network according to pedestrian accessibility of services and relative importance of them. Specifically, the goal of this project is to propose a computational design method for distributing built space in a neighborhood according to walkability gradients; given an existing/designed street network, topography and a set of locations, which are considered as important to be close to; ensuring that the majority of inhabitants would have the easiest possible pedestrian access to them. These locations can be considered as places where important services are provided such as a street where most retails are located, train stations etc. Of course such a distribution is constrained by regulations such as maximum height of buildings and minimum open-space ratio within urban lots. Walkability is formulated as an aggregate measure of closeness to the listed 'important' places of a neighborhood, taking into account the topological structure of the urban street network and walking effort based on topography. Gradients of walkability around a list of locations are found to be a factor for polycentric arrangement; and a bounded distribution technique is applied to configure the built space in the vicinity of all important locations. A rather straightforward (but not linear) approach is proposed for densification: the easier the pedestrian access to all important locations from an urban lot, the higher its density should be. Of course, in the process of densification, certain locations can be excluded from the distribution as exceptions, e.g. historically important locations.

Methodology

The paper is reporting a computational design process implemented as an interactive design tool made for a parametric CAD design environment named Grasshopper®, working on Rhinoceros® CAD program (See Figure 1). The combination of the two platforms allows for 'systematic design' coupled with 'real-time analyses. The process presented here is proposed in the form of an interactive tool, which is to support designers in configuration of neighborhoods, whether in transformation of existing ones or in creation of new ones. In this process, the street network and urban lots of a typical imaginary[3] neighborhood are modeled in (or simply imported into) Rhinoceros®

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[3] It is intentionally made as an imaginary neighborhood to emphasize the fact that the analytic-synthetic process is so

and the computational design method is embedded in a system consisting of multiple devised components. Evidently, the same computational method can be applied on any existing or designed situation[4] as well as the modeled one. In the 'model neighborhood' there exist a few number of points (they can be changed at any time by the user of course) marked as important places, where people tend to be close to. These spots are conventionally referred to as "attractors", each of which is considered to have an importance value relative to the others. The term attractor is used in the literature to suggest a gravity-like effect. This is indeed just a metaphor here; nothing is really 'attracted' towards a place, nor there is a force as such; however, it is that some effects/phenomena are stronger where closer to certain places (a similar approach had been followed in (Beirão, J., Nourian, P. & Mashhoodi, B., 2011)). There is a classical tradition of relating to the gravity law of Isaac Newton for explaining spatial interactions[5]. In the process reported in this paper a different approach is proposed, but the term attractor is chosen for its visual association.

This is a "Research in design methodology", "Research in design technology" and "Research in design application" termed and explained in (Cross, 1999) & (Horvath, 2001).Specific to urban design, it is a research on 'spatial morphology' as described in (Moudon, 2003).Theoretical foundation of the research is mainly built on the theory of Space Syntax (Hillier & Hanson, The Social Logic of Space, 1984) & (Hillier, Space is the Machine, 2007). Bill Hillier states: "If we wish to consider built environments as organized systems, then their primary nature is configurational, principally because it is through spatial configurations that the social purposes for which the built environment is created are expressed (p. 92)" (Hillier, Space is the Machine, 2007). A configurational design proposal models the inter-relationships of some spatial entities, and as such it is a 'relational model'. A 'configuration' is essentially a parametric entity, which its features are defined based on a set of geometric, topologic and mathematical parameters.

Space Syntax methodology suggests a reduced model of complex urban structures, which can be used to describe the urban network from a configurational point of view; mainly topological to be specific. However, Space Syntax method of analysis, does not address place and its peculiarities, because it is to describe the spatial structure de-contextualized. "The ability of axial maps - the conventional Space Syntax representation of urban networks- to capture movement has been proven in a magnitude of studies over the world by now. Still, we need to be absolutely clear that this is 'natural movement', which is defined as "the proportion of movement that is determined by the configuration of space itself, rather than by the presence of specific attractors or magnets" (Hillier et al 1993)[6]" (A. Ståhle, L. Marcus and A. Karlström, 2008). This suggests that we need to relate configurational analysis to idiosyncrasies of 'places' like topography and attractions. Such an approach is introduced as Place Syntax (A. Ståhle, L. Marcus and A. Karlström, 2008). Following a similar approach to Place Syntax, in order to address place-related factors affecting pedestrian movement, the ultimate aim of this research is to combine configurational analysis with a set of computational methods and techniques capable of addressing issues like attraction of places that might affect the choice of people for walking on a certain street for instance.

Analysis

There are several steps in the analytic process for finding the gradient of walkability over the modeled neighborhood. The initial step is forming the network by street centerlines. In this step, every street's centerline is cut into equally-long segments in order to create a finite set of locations on the network. These locations can be all potential origins and destinations for pedestrian commutations. To calculate the walking distance between two points, there needs to be a determinate basis such as the length of the 'shortest path' between the two points. In the presented process, the shortest path is found using *Dijkstra*[7]'s shortest path algorithm. From each attractor point to all locations a list of network distances is found according to 'ease of walking' on the topographic surface and minimum possible distance through the topological network[8] (See Figure 1). Once a distance value (toward a certain attractor) is assigned to every single location on the network; they can be aggregated as a list of distances

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generic that can be applied anywhere.

[4] such as radial networks, rectangular networks or any complex network

[5] A review of such models can be seen in (Kingsley E. Haynes, Fotheringham A. Stewart, 1984)

[6] This quotation is taken from: (A. Ståhle, L. Marcus and A. Karlström, 2008)

[7] Dutch computer scientist Edsger Dijkstra (1930-2002)

[8] An alternative 'angular shortest path' method is under implementation in the process; that is a shortest path algorithm which takes into account the intelligibility and geometric continuity of a potential path in any choice. (Turner, 2007)

to the attractors, given their relative importance. This can form a basis for computation of a 'walkability gradient', which reveals both the inherent structure of network and idiosyncrasies of the neighborhood represented in relative weights of important places and its particular topography. A visualized gradient map of walkability values is shown in Figure 1 & Figure 2. Walkability values apply to the locations on the network; however, for every single urban block, it should be determined, from which location on the network it is accessible. Afterwards, a relative walkability factor can be assigned to each of urban lots that forms a basis for distribution.
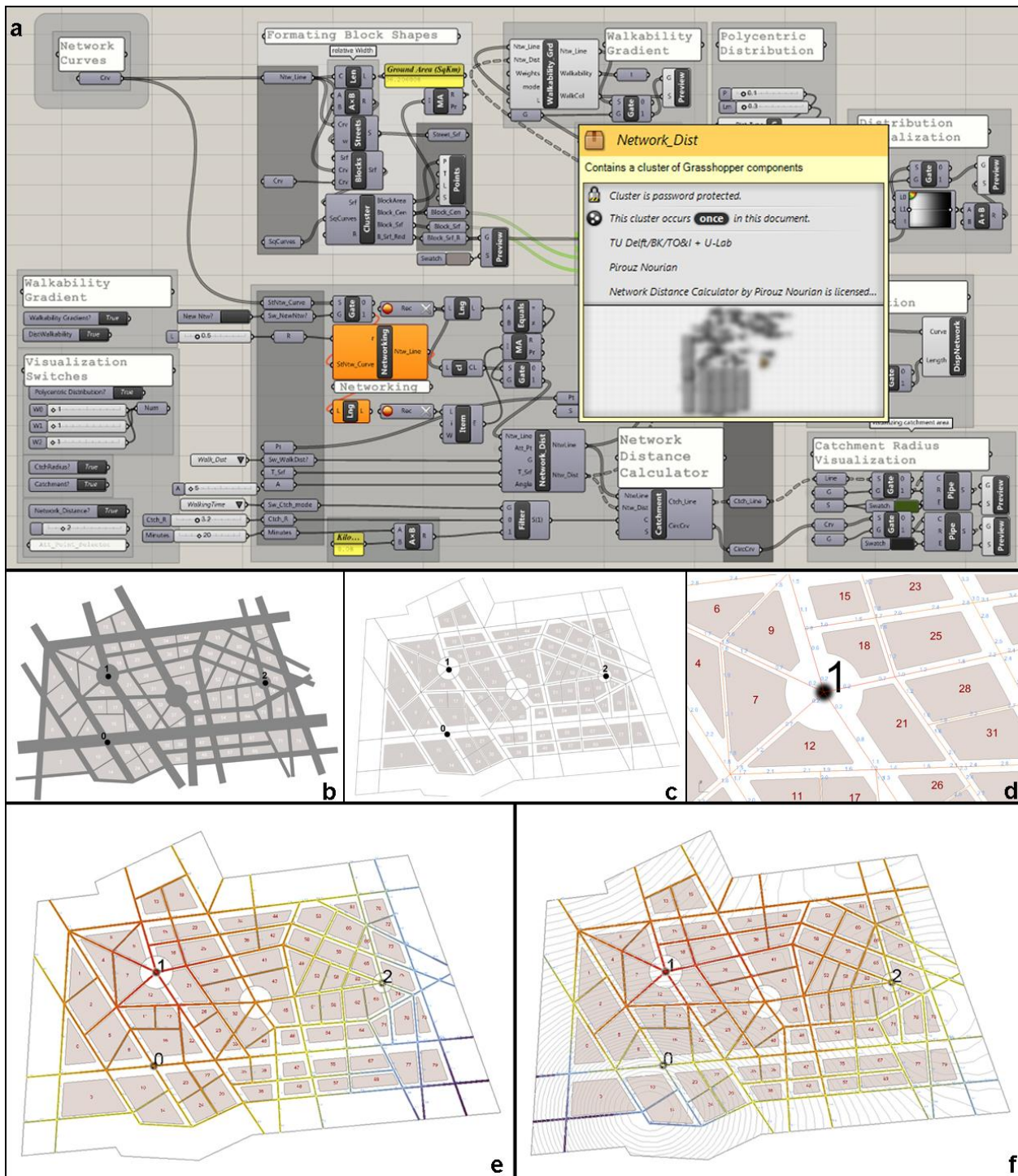

Figure 1 (a) The computational design system made in Grasshopper® Visual Programming Environment. (b) a typical imaginary

Definitions

<u>Catchment Radius:</u> There can be two measure of distance on a street network; one is referred to as the Euclidean distance, which is the length of a straight line drawn between origin and destination; the other one is sometimes referred to as Manhattan distance and is the distance between origin and destination through available street network. A catchment enclosure delineating the furthest accessible locations closer than its radius in terms of Euclidean distance can be easily drawn as a circle, as the locus of points equidistant to the origin. However, in order to draw the catchment enclosure according to the network distance, there needs to be first a measurement of network distance. In a rectangular urban network such as those of Manhattan's neighborhoods, there can be alternative equidistant routes given a single pair of origin-destination. To calculate the distance in a non-particular given network, the 'shortest path' between the above pair of points should be found first and its length be considered to be the network distance between the two points. For catchment analysis, it is necessary to find the distance of every single location to the point of interest. When such a list of distances is available, locations closer than a certain range are considered to be in the catchment enclosure (See Figure 2). Such catchment enclosure would not be a circle unless (approximately) when the origin is the center of a radial grid with a large number of cells is polar direction (sectors).

<u>Temporal Catchment:</u> Considering the normal walking pace of a human being to be about 5 Km/H, we can calculate how far a person can walk within a minute as follows: $5\ Kilometers/Hour = 83.33\ Meters/Minute \cong 80\ Meters/Minute$. This number allows for interchanging spatial and temporal distance measures easily; e.g. 15 minutes of walking could be considered as (typically) 15 times 80 meters equal to 1.2 Kilometers (See Figure 2).

<u>Walking Impedance:</u> In finding the shortest path and the minimum distance between a given pair of origin-destination; we can assume that the more altitude difference a certain piece of network has the more it impedes walking through it. This impedance has been calculated and taken into account (see Figure 1); however, except the example shown in the Figure 1 (f), all the rest of images show a flat situation, avoiding any possible confusion.
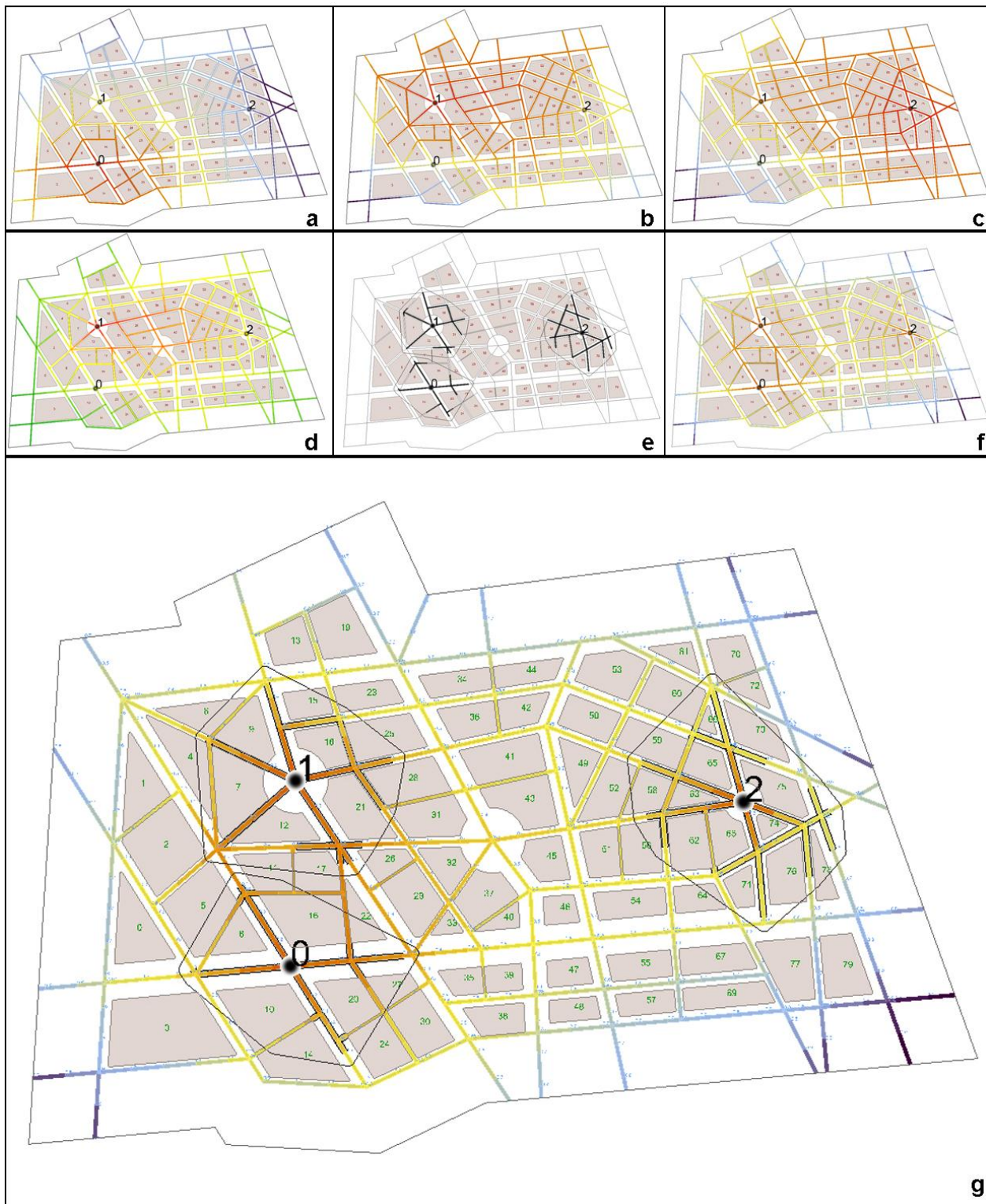
Figure 2 (a) network distance gradient from point #0; (b) from point #1; (c) from point #2; (d) aggregated gradient of walkability; (e) catchment radii based on network distances and 20 minutes of walking; (f) vicinity analysis; (g) vicinity of attractors and catchment radii combined

Synthesis

The basic assumption of the paper is as follows: to promote pedestrian mobility, the distribution of residential density should become consistent with walkability gradient of a neighborhood, considering that the better access a certain place has -by walking- to important places (attractors) of the neighborhood, the more it is suitable for living and thus it is better to become more dense in terms of built floor-space (See Figure 3). This indeed is a simplistic, commonsensical and non-inclusive approach to urban densification; however it is merely proposed as an example of how configuration can be based on analysis. Self-evidently, many other factors can be aggregated with walkability to make the ultimate decision on a particular neighborhood. Possible other factors are foreseen as potential inputs (like maximum allowed building height and land price) to be aggregated with walkability for a more advanced decision-making process.

The design process reported here is literally a synthetic process, i.e. it is based on an aimed aggregation of analytic results into a single configuration. By configuration, a certain way of distribution is meant, as it determines how things are to be related to one another. The choice of distribution technique and its arrangement are intentionally made as 'design decisions'. Specifically, in this process -using a list of relative walkability values assigned to all urban lots through analysis- a bounded descending distribution technique is used that actually configures the built space over the area of intervention.

Lawson (Lawson, 1980), has proposed a description of design process as follows: "Design process as a negotiation between problem and solution through the activities of analysis, synthesis and evaluation". According to this point of view, this process seemingly lacks an evaluation framework. However, in fact evaluation is not present in the form of a feed-back mechanism, and that is because, although simplistic, it is already implemented in a feed-forward manner[9]. Meaning that, the qualitative goal -promotion of pedestrian mobility through distribution of density in congruence with walkability- is being satisfied as desired. Nevertheless, an all-inclusive framework and method of quality evaluation is indeed absent in the process. This is because evaluation is a topic so important in itself that the authors decided not to address it directly here. In any case, the analytic-synthetic process can be easily integrated with a potential automated evaluation process.

Reflections and afterthoughts

The density distribution process is (and should be) questionable; but no doubt, measuring the walkability of a neighborhood may propose many alternative approaches. This paper is mainly to launch the discussion on how to distribute entities over a street network, given the preference of pedestrian mobility. This is to say, it is just a step towards an integrated approach to configurative design; in which the way things are to be related to one another is the driver of design process. In this case, the inherent topological and geometrical structure of a street network, plus the relative importance of certain places to the inhabitants of a neighborhood show us how the neighborhood is, in terms of walkability. In the next steps, firstly one can try many alternative possibilities watching the consequences of any change; secondly, such a method provides for informed decision making in urban planning and design.

It is worth mentioning that the very definition of a 'neighborhood' could possibly be revised through walkability measurement (Moudon, 2003). In this case the catchment enclosure can be formed based on a typical measure of walking time and its equivalent distance. For instance, a catchment area with the radius 30 minutes walking (2.4 Kilometers wide) around a group of important attractive places -centered where a minimum average distance place is located- can be found as shown in Figure 1.

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[9] In many situations, a clear analysis of a problem, combined with goodness criteria, already suggests the way certain processes should be modified, in order to improve the situation. In such cases, there needs not be any random generation of solutions and a search method for finding the best options nor any feedback mechanism at all. In many cases we find that a feed-forward strategy would do much better and clearer; that it can indeed guarantee certain qualities of the outcomes; and that we do not need any feedback mechanisms to ascertain those qualities. Though, it is quite fashionable to talk about feedback optimization as the term has been widely and carelessly used in the public media.
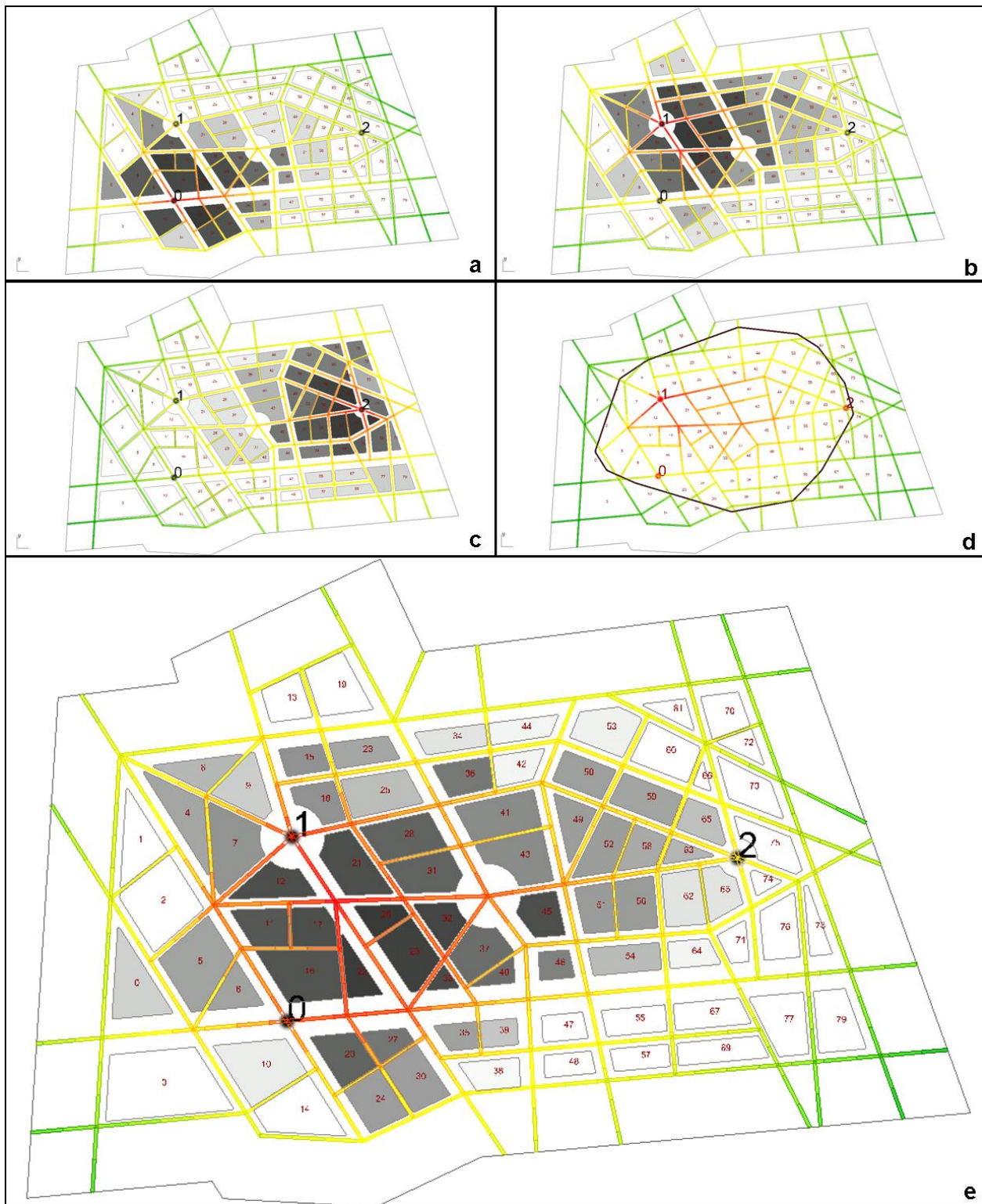
Figure 3 The greener the color, the less accessible the location; the blacker the color the more dense the urban block (a) polycentric distribution of density, with the maximum weight of point #0; (b) with the maximum weight of point #1; (c) with the maximum weight of point #2; (d) a revised border of neighborhood according to walkability; (e) polycentric distribution of density, with equal weights of importance

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