A TYPOLOGY OF BLOCK-FACES

A Dissertation
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in Architecture

Georgia Institute of Technology

August 2013

A TYPOLOGY OF BLOCK-FACES

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Date Approved: June, 28th 2013

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SUMMARY

The size, configuration and relationship of urban blocks and building footprints are vital to making a livable and sustainable city, with a sense of scale but also a sense of dialogue between elements. This dissertation documents the interface of public and private realms at the edge of the block and proposes a typology of block-faces. The block-faces respond to buildings (the internal load of blocks) and street structure (the external load of blocks). It is argued that the block-face and not the block should be the basis for thinking of city form.

The City of Atlanta is used as a case study because of the spectrum of conditions and possibilities that it illustrates. The quantitative approach of this work builds upon a research tradition of analytical and quantitative urban and building morphology. A method is proposed for assessing the potential of the existing city prior to design intervention and for evaluating alternative scenarios for future developments. The ultimate goal is to provide tools to design more sustainable communities by bridging differences of scales and by better understanding how urban design parameters influence the development of built form and architecture.

CHAPTER 1

INTRODUCTION

In cities, the variety of functions (or land uses) and land values (economic) drives the presence and the morphology of buildings. The diversity of land uses is often associated with a diversity of urban conditions depending on several factors such as the price, size, and accessibility of plots. Land uses and land values significantly interact with the structure of streets and blocks, producing the physical expression of urban conditions. As a result, they all tend to co-vary with each implementation of new developments and changes to pre-existing conditions. Based on this notion, this dissertation concentrates essentially on the morphology of cities with the understanding that city form, including streets, blocks and buildings, cumulatively expresses particular needs as they arose over particular moments of time. However, the street network and the configuration of urban blocks usually remain more stable over long periods, to act as the framework, planned or unplanned, for the evolution of land uses, land values and built forms. In this dissertation, land uses and land values, are not taken in to account except insofar as they are expressed in built form. The focus is on the physical outcome that embeds land uses and values. In short, the research is only looking at streets, blocks and buildings that constitute the physical form of the city, and the relationships they establish.

Considering that streets and blocks are the long term stable framework for the evolution of the city, the thesis answers the question of how the impact of the street network on building configurations interacts with the impact of block morphology. In essence, the conceptual difference between the two kinds of impact can be stated as follows: street networks act as larger scale spatial structures that determine the relative accessibility of different locations to create hierarchies of streets and places; urban blocks, by virtue of their size and shape, constraint the size and shape of building footprints than can be built. Thus, while the locational hierarchies established by the street networks affect the desirability of a particular building or a particular cluster and mix of buildings at a particular place, the geometry of urban blocks affects their feasibility.

Almost by definition, urban layouts accommodate variable patterns of buildings at a given point of time, and over time. However, insofar as cities are differentiated wholes, and insofar their vitality depends on the accommodation of a variety of uses, programs and forms, the following questions arise: how far should the design of system of streets and blocks aim towards a variety of sizes, shapes and conditions, and how far should it be aimed towards the creation of a more homogeneous and flexible underlying structure?

For example, in Figure 1, the locally homogeneous square grid does not provide any incentives on edge variations based on its sole morphology. However, despite the homogeneous conditions on the edges of the blocks, there are a variety of building configurations – from single family houses to towers – and a variety of land uses – residential, commercial, offices and mixed. If the larger street network is analyzed, it displays syntactic variations relative to continuity and connectivity that relate to diversity and density of building configurations. The hypothesis is that the syntactic properties of street have a stronger impact than block morphology on the amount and diversity of building configurations. No deterministic model of the relationship between syntactic properties, block morphology and building configuration is to be expected, nor would it be desirable. This thesis contributes instead to the discussion of the nature and conditions of differentiation and variety within urban form.

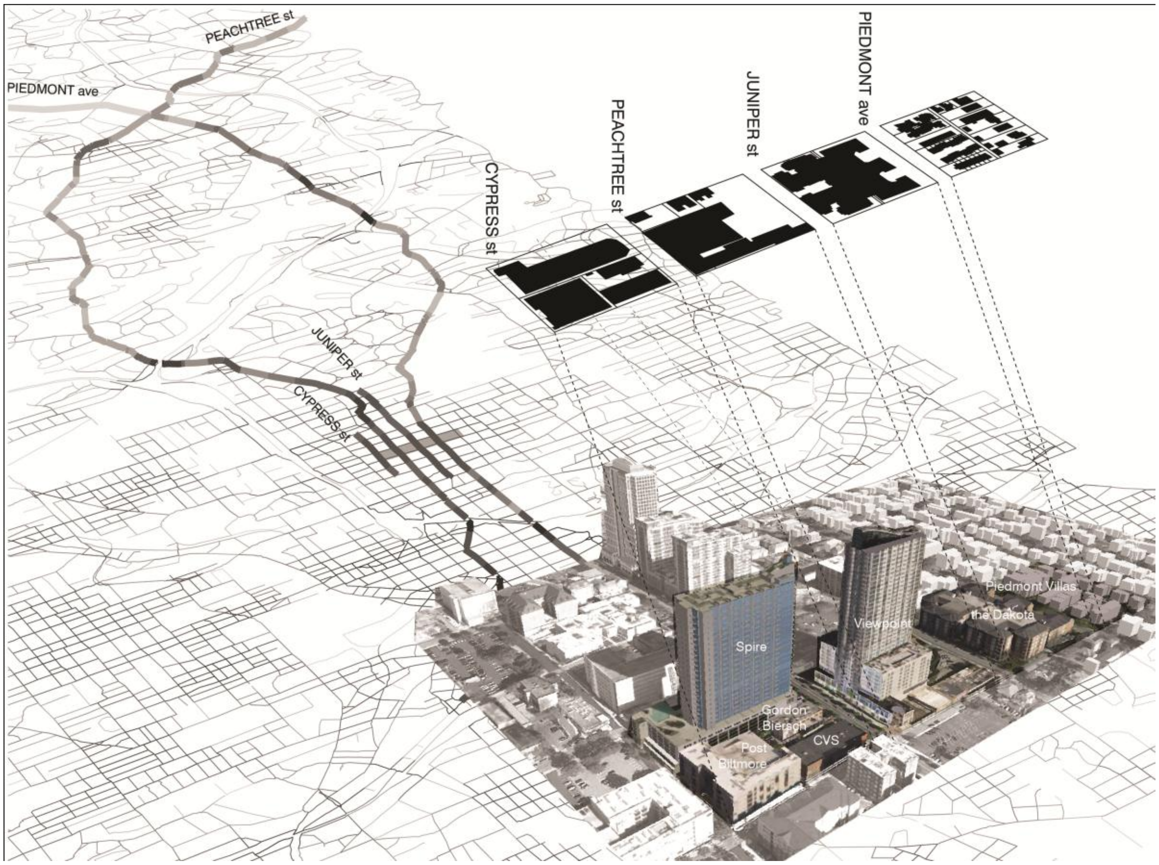

Figure 1. Cross-section of Peachtree in the Midtown neighborhood.

Studies in urban morphology typically look at the interactions between urban block size and shape, and patterns of buildings. Typically, however, the impact of the larger scale syntax of street network is not taken into account. On the other hand, studies in space syntax have looked at the interaction between street connectivity, land use and development density, but have not specifically addressed the geometry of urban blocks. This thesis proposes that the development of urban blocks expresses two kinds of loads: the building footprints with their density and configurations, and the larger street network with its structure of connections. The thesis examines how these two kinds of load interact to produce urban form. It focuses more specifically on the block-face as an interface of these internal and external forces or loads.

From a more theoretical point of view, the block-face typology is proposed as a way to link, at a particular point in time, the dynamic activity carried by the street layout (flows) and the more static built forms carried by the internal surface of the block. Studies of block and street typologies have hitherto been developed as parallel lines of inquiry, even when attempted by the same authors. Because the relationship between buildings and streets happens at the block-face, the development of a block-face typology is an original and well-defined contribution to the field that serves to link the different scales and forces that underpin all urban design.

The secondary contribution is a normative one. It proposes a way to measure and assess existing urban form in the context of North American sprawling cities. The morphology of our cities entails fundamental problems but also, when studied carefully, hints for their solutions. In recent decades, city growth and urban identity have become more central to public debate. The form of North American cities, particularly as accrued since the 60s, has been characterized principally by 'urban sprawl'. The diverse solutions proposed in order to remedy the disadvantages of sprawl have focused on smart growth', 'sustainable cities' and 'urban ecologies'. The challenge has been to find an alternative to zoning that will take into consideration the flexibility and diversity that characterize the relationship of built form and street networks. Solutions that deal with sprawl should be able to accommodate changes as part of the inward and outward growth of cities without detriment to the large-scale functioning structure. Of particular interest to this thesis is the question of whether an area developed as a suburb can get more densely urbanized over time; and, if it can, which particular suburban sites are good candidates for the initial steps towards denser urbanization.

To summarize, the primary question is how to maintain and create diversity within urban form to provide a more flexible local structure for development while keeping a cohesive and stable global syntactic structure. It proposed that the syntactic street structure co-varies but also influences building presence and configurations more than the block morphology considered in isolation. This dissertation argues that if one is to intentionally aim towards urban diversity while also seeking to maintain a stable global structure, the current conditions should be described and measured by block-face; proposals for re-development should be evaluated according to this same principle. By their nature, block-faces participate in defining the edges and character of the street network; they act as the interface between architectural form and urban form.

The secondary question, discussed on the basis of diversity and stability measured according to block-faces, pertains to the City of Atlanta. The thesis proposes methods of representation that highlight both the present structure and the future potential of the city. A normative assumption is being made, namely that the present pattern of urban sprawl should accommodate future patterns of growth to create conditions of greater density and variety than currently prevail. The consideration of the structure of the City of Atlanta also reinforces the suggestion that zoning should be thought of in relation to urban form and more particularly in relation to prevailing and desirable conditions along streets and block faces rather than over areas. In a nutshell, what is being zoned is three dimensional built form and two dimensional building footprints, but what is being produced functions according to the structure of the street network and is also perceived and understood accordingly. The thesis contributes to the larger task of linking the structure of the street network to zoning, a task advocated and pursued in much recent literature.

Method

Consistent with these aims and issues, figures, diagrams, and tables are as important to the thesis as the text, if not more important. The argument is largely made through the development of representations and statistical descriptions of the relevant phenomena, to bring them under the purview of clearly defined ideas. Representations and statistical descriptions are combined into typological atlases. The typological atlas, as proposed here, is an apparatus that maps typologies combining statistical methods, including methods of cluster analysis, with GIS representations. Typology groups data by similarities and the atlas visualizes the geographic distribution and spatial interrelationships of typological data. Atlases serve as a basis to assess the existing city in order to test future scenarios. Typological atlases are part of a methodology that is essentially quantitative.

The methodology builds upon a research tradition of analytical and quantitative urban and building morphology. The research is possible due to the continuously accelerated evolution of computation and the increasing availability of fine-grained data. The mathematical classification of urban and built form allows the precise identification of commonalities and differences between designs. Classification is a way to group elements with similar characteristics so as to reveal their potential evolution, function and behavior. The classification of designs is traditionally based on visual and formal resemblances that are identified in order to propose types. The designer, who then uses the types, knows that they will have certain properties. Design is an exercise of composition that manipulates forms to produce configurations. These forms are either built or non-built and can be two- or three- dimensional. In this dissertation, the role of quantification and formal analysis is to structure the exploration of possibilities given that geometry and topology impose their own limitations upon urban and built form. For example, the arrangement of three rooms into a plan can take different configurations with or without symmetry of shape, adjacency or mutual connectivity (Steadman 1983). The choice of the best configuration remains in the hands of the designer. The mathematically possible arrangements or configurations open up the possibilities for designs, but do not determine them. They only reveal the potential linked to certain choices of forms, or types of shapes and their configurations. It is also important to note that in this thesis the typology is not final. Different emphases produce different types based on aspects of morphological properties, syntactic properties or a combination of both.

Case Study

The City of Atlanta in Fulton County, 29 000 hectares, is chosen as a case study in order to test methodologies and explore and develop theoretical ideas. The area is large enough to represent the global structure of the city and does not include non-urbanized pockets; it lends itself to considering how local and global scales of configuration, connections and organization are interfaced. The city of Atlanta is an appropriate case study because it has urbanized areas that take very diverse forms. The heterogeneity of local structures presents opportunities to analyze the impact of global structure.

The city of Atlanta is a good example of North American “urban sprawl”; at the same time, it has a historical core that represents the more traditional dense city with colliding street grids. The building stock of the city also exemplifies a diversity of conditions; these conditions are not necessarily typical of those found in other cities, nor can they be presumed to be optimal. The exceptionally large blocks found in many parts of the city support building morphologies that may not be possible, or needed, elsewhere. Studies based on other cities would be necessary before the generalization of the findings reported in this dissertation. That said, Atlanta is as good a case study as any, precisely because of the spectrum of conditions and possibilities that it illustrates.

Outline

The dissertation is organized into 8 chapters. After the introduction, the second chapter of the dissertation contextualizes the main question and hypotheses and reviews relevant literature. The discussion focuses on the urban block as the key element in city design. Its disappearance and reappearance in urban design theory and practice is tracked over the last decades with an emphasis upon the proposed dimensions for effective urban blocks. This leads to the proposition that the block-face and not the block should be the basis for thinking of city form in general and zoning more particularly. The following chapter introduces the case study and details on the method of inquiry. It proposes a definition of block-face that challenges the traditional view of the city and raises questions on how to deal with less traditional urban form. To clarify it, the fourth chapter starts with a description and quantification of the shape and size of blocks, leading to a characterization of the existing conditions of the city in terms of block morphology. These are parameters of shape and dimensions that can be acted upon during the design phase. Then the focus shifts to the block-faces as elements that respond to the internal load (buildings) and the external load (streets) in chapter 5. The city is presented as a functional structure that can potentially produce activity, support social interaction, provide a sense of identity or support economical needs. The functional properties of structure result from the balance between building load and street load. An attempt is made to link the design of blocks to types of load. More particularly, potential local design moves are contextualized and evaluated against the larger functional structure of the city.

Chapter 6 applies the proposals made in the last three chapters to the distinct case of Atlanta and to the issue of sprawl. A first classification provides a complete and accurate statistical profile of Atlanta's block stocks based on morphological properties, and based on building and street loads. The typological atlases mapping these classes provide a visual and statistical state of the existing urban conditions. Against the traditional issues of sprawl such as low density, connectivity and accessibility, blocks are evaluated in terms of their potential to change or evolve towards a less sprawling tendency. By looking at block-face, the vision of the block as a unit of intervention is challenged by the presence of different connectivity values for a single block, which allows a more refine understanding for the location of new developments. Chapter 7 builds upon these observations and concludes by focusing on the relationship of block-faces to the larger surrounding context. It highlights the relationship of block morphology with the functional properties of their block-faces. This section shows that large-scale structure prevails over the morphology of each individual block as a driver of building presence. This supports the claim that designers should understand the impact of global structure on their urban proposals. The final discussion extends this observation, reviews the limitations of the thesis and describes future lines of work.

CHAPTER 2

THE EVOLUTION OF THE URBAN BLOCK SINCE 1960

"The grid of streets and plots from which a city is composed, is like a net placed or thrown upon a ground. This might be called the framework of urbanization. That framework remains the controlling factor of the way we build whether it is artificial, regular and preconceived, or organic and distorted by historical accident or accretion. And the way we build may either limit or open up new possibilities in the way in which we choose to live" (Martin 1972).

Cities, either planned or organic, produce a wide range of blocks and buildings that vary in size and shape. They are the result of different approaches to urban design, but are all built upon the fundamental generative elements of urban form: the building, the plot, the block and the street. In the 1970s, architects and urban designers raised the question of whether a relatively small block size should be preferred, to produce dense street networks. Smaller blocks, however, necessarily constrain the kinds of buildings that can be accommodated. However, some of the more sophisticated attempts to design urban layouts that accommodate a hierarchy of different blocks were made in the 1960s. Architects and urban designers understood that cities are likely to require a variety of block sizes and that these should be arranged in particular configurations relative to one another. Since then, alternative theoretical positions relative to block design have been associated with distinct normative values and intents.

The review of literature, projects, and proposals presented in this chapter is organized in two parts. The first part presents proposals by architects, urban designers and planners that attempt to define ideal block shapes and sizes that contrast with modernist proposals. Similar discussions of the urban block are also set in the context of the debate, mostly in the US, over the advantages and disadvantages of sprawl and compact cities. Both in Europe and in the US, the criticism of modernist planning and/or urban sprawl entailed a criticism of functional zoning as an instrument of separation and segregation. However, the review of literature suggests that urban design practice, in focusing locally on block and street design, still works within "zones" that do not take into account the global dynamic of cities.

The second part examines the field of research and scholarship in urban morphology. Urban morphology is the most obvious knowledge base that can support conclusions relative to the questions raised by urban design practice. The data and methods that it uses help make sense of the built environment in terms of urban units such as the street, block, plot and the building. Morphological research offers evidence of systematic relationships between block shape, building configurations and street connectivity; however, very few studies combine streets, blocks and buildings to provide a more complete system for assessing the performance and potential of city layouts to accommodate changes. This review concludes with a discussion of the choice of urban morphological units used on this study. It highlights some limitations of current approaches and suggests, more particularly, that the critical unit of analysis is not the block, as a whole, but rather the block-face.

2.1 Urban Proposals

The 1960's marked an important threshold in the history of the modern city. On one hand, they are associated with the completion of major projects of city design inspired by the ideas of the pre-war modern movement, namely Brasilia (planned by Costa) and Chandigarh (planned by Meyer and Le Corbusier).On the other hand, they witnessed a rigorous criticism of the modernist ideal in city planning, namely the super-block with free standing buildings arranged in open space. Authors such as Aldo Rossi emphasized the virtues of the traditional city (Rossi and Vitale 1966) and, more specifically, the importance of a spatial organization based on streets, squares and urban blocks whose perimeter is usually defined by dense construction. An illustration from Collage City (Rowe and Koetter 1978) describes the city in terms of relationships of figure and ground and provides an emblematic reference the rejection of modern urban space in the 1970s (Figure 2-b).

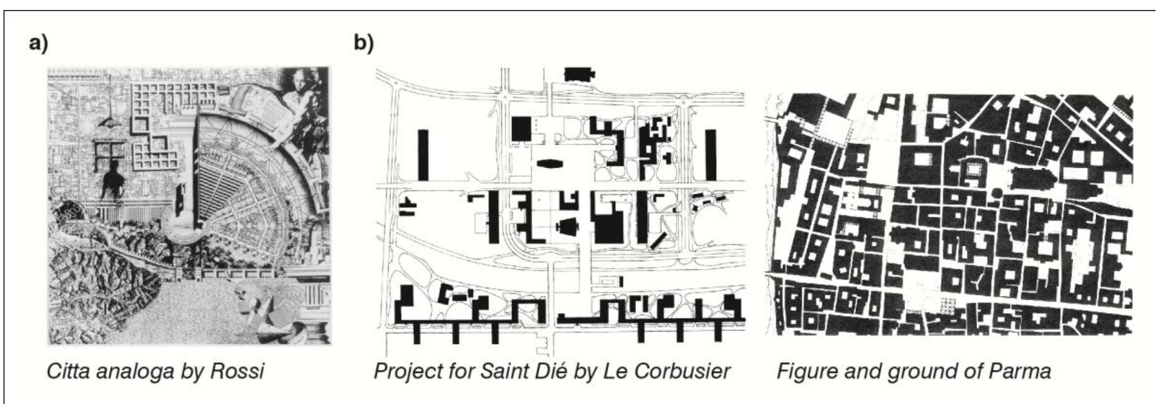

Figure 2. a) "La cittˆ analoga" by Aldo Rossi showing the city in a continuous time with layers of history (Source: Lotus no.13 1976). b) Figure and ground of Saint-Di□, project by Le Corbusier, and the traditional city, here Parma, illustrated by Rowe and Koetter who argue for the return to a city of dense blocks (source: Rowe and Koetter 1978).

Islamabad, designed by Doxiadis in the late 60s, holds a paradoxical position within this emerging spectrum of debate because it adopts the principles of the superblock while at the same time seeking to produce an urban fabric based on a hierarchy of streets, blocks and squares. Figure 3 compares superblocks from Brasilia, Chandigarh and Islamabad to provide a graphic summary of the state of city design practice at the time.

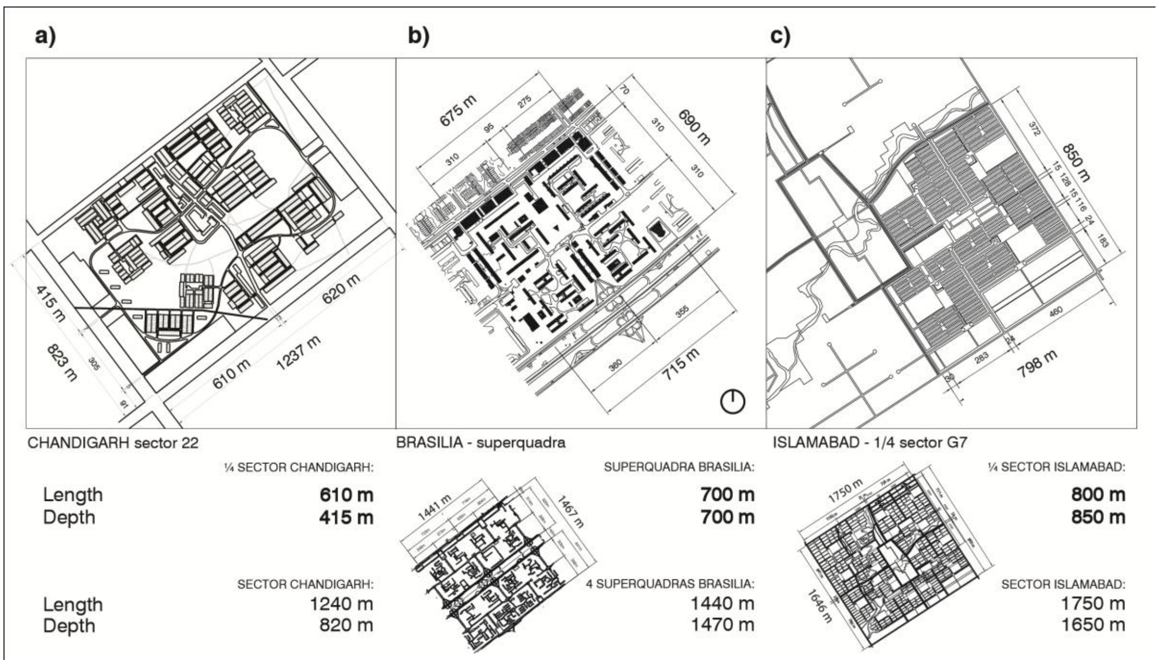

Figure 3. a) A sector in Chandigarh (Sector 22), 1240 by 820 meters with dendritic streets (Le Corbusier); b) Combination of four superquadras in Brasilia, 1440 by 1470 meters, with their streets layout to access buildings (Costa); c) A sector in Islamabad (G7), 1750 by 1650 meters, with its hierarchy of streets, blocks and parcels (Doxiadis) (source: (Peponis, Vialard et al. 2009)).

The critics of modernism saw the disappearance of the block as the most critical problem associated with modern city design. To them, the importance of the block in controlling the location of buildings is best demonstrated by the failures of the modernist superblock to indicate appropriate locations for buildings. When blocks do not control the location of buildings, buildings are disassociated from the street; “Formes urbaines: de l'îlot à la barre” describes this transformation (Castex, Depaule et al. 1977). Since the 1970s, much urban theoretical debate and many urban design proposals in Europe have refocused on block design as a means to reconnect the building and the street. These European proposals do not take as a point of departure the same issues as those raised in the North American debate. In the United States the renewal of interest in the traditional morphologies of the urban block was primarily prompted by the rejection of urban sprawl even though the critique of modernism also played a role; indeed the demolition of Pruitt Igoe was taken by many (Jencks 1977) as another emblematic moment marking the rejection of modernist planning principles.

2.1.1 The Debate in Europe

Modernist ideals of city form included the superblock, a hierarchical street system, and growth by accretion of pre-designed units (Figure 3). Counter-proposals to the modernist ideals argued for the continuity of the city. Such proposals emerged in the 1970s in Europe around major figures such as Rossi (1966) and Robert Krier (1979). For Rossi, the continuity of the city is physical, but should be reinforced by continuity in time. For Rossi, the layering of history created a structural framework for new design that can be built upon. This contrasts with the modernist desire for a ‘tabula rasa’. Rossi looks for the underlying structure of a city to evolve and adapt to new uses, viewing the city as the repository of collective memory. One way to achieve collective memory is to translate it into the physical continuity of urban form by the layering of buildings into larger, existing urban structures (Figure 2-a). For Rob Krier physical continuity is achieved through the design of both the void and the built space (i.e. street, place and quarter). However, he remains focused on ideals rather than modes of implementation; his proposals are discrepant with contemporary modes of living. Rob Krier was a key advocate of the notion of "*spatial continuum of a cohesive traditional urban structure*" (1979). This spatial continuum provides orientation and channels pedestrian movement. Rob Krier proposes morphological configurations where buildings and blocks are organized to shape open space as strongly figural, as shown in Figure 4-b. However, the open space depicted by Rob Krier is often limited to the square and its adjacent streets. There is no evident effort to address the larger dynamic coming from the overall structure and hierarchy of the street network.

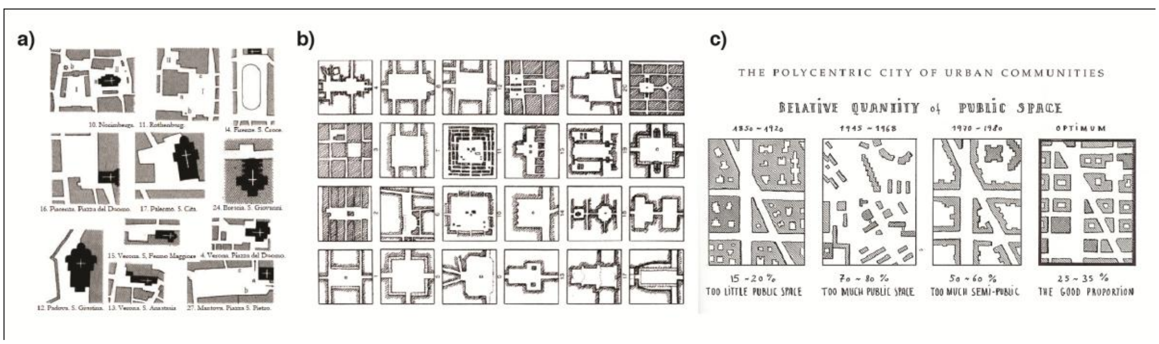

Figure 4. a) Piazzas surveyed by Camillo Sitte in "City Planning According to Artistic Principles" (source:(Sitte 1889)) The void and the built as spatial continuum articulated around urban squares of the concept of urban space from "Typological & morphological elements" (source: R. Krier 1979). c) Options for the "quantity" of public space (source: L. Krier 1978).

Leo Krier (1978) proposes blocks that can achieve a balance between open space and building density. He argues for a particular level of continuity and critiques the over-densification of urban layouts (Figure 4-c, leftmost diagram). One of his proposals is the building-block, a block sized as to accommodate a single building (Krier 1978). Krier attributes a minimal but sufficient size of 22 by 22 meters to the block-building. His contemporary, Manuel de Solˆ-Morales (1978) suggests a 60 by 60 meters block as the minimum desirable block size. Such extreme proposals clearly seek to restore a smaller-scaled environment where buildings and blocks are in very close interaction.

Late in the 1970s, architects and urban designers began to focus more on the adaptability of urban form to different uses and functions. The adaptability of the block to different functions was implemented and tested in several key projects in the 1980s. The second International building exhibition, "New-IBA", held in Berlin in 1979 and led by J.P Kleihues, called on architects[1], including Rossi and Krier, to make proposals for urban renewal and the critical reconstruction of the city. In this project, vacant blocks are given to architects to design a building according to certain guidelines that stressed the re-creation of traditional streets, block and squares (Figure 5-ab). Such projects demonstrate how existing blocks can shape the configurations of buildings to accommodate different functions, such as housing, commercial, and office uses.

The adaptability of the block to different functions and building types is best shown in the work of Derek Walker for the city center of Milton Keynes (CMK). Walker (1982) designed blocks 320 meters long and 150 meters wide that are large enough to accommodate a stadium, but can be fragmented into four smaller, 72 by 150 meters blocks for offices or commercial purposes (Figure 5-c). The rationale for the size was to achieve an ideal city form that accommodated commuting as well as walking.

[1] Peter Eisenman, Vittorio Gregotti, Herman Hertzberger, Hans Hollein, Arata Isozaki, Rob Krier, Aldo Rossi and James Stirling.

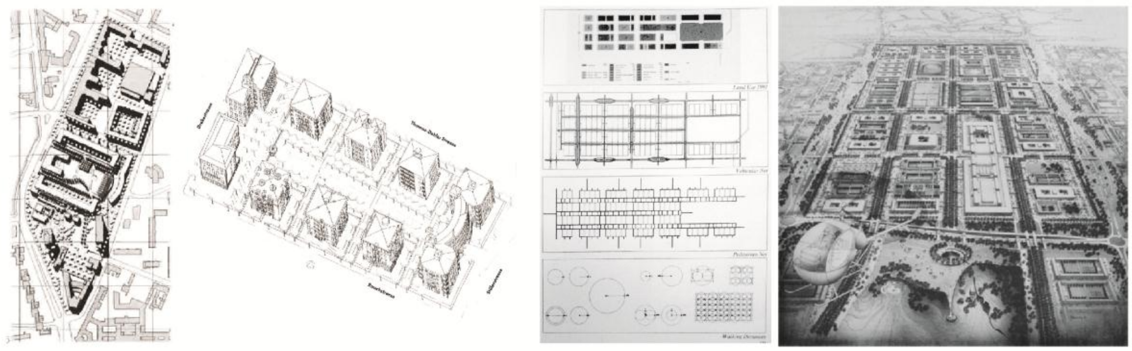

Figure 5. IBA Projects proposed by a) Kollhoff & Karch and b) Aldo Rossi for two different blocks in Berlin (source: The architectural review 1987). Land use studies and movement systems Central Milton Keynes (source: Walker 1982) with an illustration by Jacoby (1978)

By designing for an existing urban layout, IBA projects used the potential given by an existing block structure, while the new downtown of Milton Keynes shows an example of a new urban fabric designed with the intent of adapting to future changes, including different building configurations. These two examples anticipate the design approach that would be proposed by new urbanists in the United States in the 1980s. This design approach would come to advise that the infill and construction of new towns be based on small blocks, street connectivity and dense building.

2.1.2 The Debate in the US.

The North American proponents of a return to a city of higher street density inherited a somewhat different urbanism. The garden city ideal of houses on their grassy plots strongly resonated with aspirations for vernacular settings, while the modernist's tall free-standing building in the park was adopted as a valuable model for economic growth. The modernist heritage of buildings in nature and the separation of functions have produced the 20th North American city, most of whose area is composed of the sub-divisions and strip malls that are commonly referred to as “sprawl”. This form of development has usually neglected the urban block. Instead, land is segmented into isolated leapfrog developments that are further fragmented into smaller subdivisions, each with a self-contained system of internal dead-end streets to access single family detached houses on an optimized subdivision of properties. Block shapes emerge from streets networks branching inwards from major bounding streets, creating very complex and meandering block boundaries. In other cases, the street is the point of departure for developments such as strip malls. “Learning from Las Vegas” (Venturi, Brown et al. 1972) describes “strip” streets as generating an urbanism in which the relevant scale is linked to the speed of the car and has little to do with the pedestrian scale. Blocks serve to punctuate the streets. Blocks are not primary generators of urban form, neither in subdivisions nor in strip designs.

New urbanism recognizes sprawling neighborhoods with housing subdivisions that are disconnected from the streets (the infamous lollipops and cul-de sacs), shopping centers and office parks that show segregation of land use, sparse and overly large civic institutions and too many roadways in general as inherited problems (Duany, Plater-Zyberk et al. 2001). As answers, new urbanists propose reconsidering the block as a constructive element to create urban continuity and walkable communities. Seaside in Florida (Duany Plater-Zyberk 1985) and Laguna West in California (Calthorpe 1993) are two communities that have pioneered the implementation of the ideals of new urbanism.

The block emerges as one of the central concerns of the charter of New Urbanism: '*We dedicate ourselves to reclaiming our homes, blocks, streets, parks, neighborhoods, districts, towns, cities, regions, and environment.*" (CNU 1996; Leccese and McCormick 2000).The charter offers particular attention to "the block, the street and the building" and proposes solutions that are normative, such as "form-based codes" and the use of the transect to govern form (Duany and Talen 2002; Parolek, Parolek et al. 2008). Each of the solutions addresses different aspects of the problem of sprawl by presenting regulations and a standard model for design. Laguna West in Sacramento implemented guidelines to create a walkable community (1991). The design effort is in the articulation of public spaces, but the block layout, while adapted to pedestrian scale, is not entirely satisfactory because of its lack of connectivity due to its dendritic streets. In Seaside, dendritic patterns are absent, and the 1985 master-plan by Duany and Plater-Zyberk is a more grid-like layout. It hosts buildings by different architects, including Leon Krier[2] and Rossi. An illustrated urban code, a form-based code also termed a *smart code*, provided guidelines to specify the location of buildings depending on the parcel type.

The new urbanist form-based code associates a physical outcome with clear and precise standards that offer predictability. Per new urbanist authors[3], it is *"a method of regulating development to achieve a specific urban form. Form-Based Codes create a predictable public realm primarily by controlling physical form, with a lesser focus on land*

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[2] Leon Krier worked as a consultant in 1983 for the master-plan and made some suggestions concerning the "urban layout (blocks and spaces)"; his suggestions were partially taken into account.

[3] The Form-Based Codes Institute (FBCI) was established in 2004 by Peter Katz, author of The New Urbanism, together with Carol Wyant, and 15 other New Urbanist architects, planners, and attorneys including Victor Dover, Andr□s Duany, Geoffrey Ferrell, Joe Kohl, Mary Madden, Stephen Mouzon, Stefanos Polyzoides, Samuel Poole, Steve Price, Robert Sitkowski, Daniel Slone, and Bill Spikowski.

use, through city or county regulations" (Parolek, Parolek et al. 2008). One of the key concepts is the transect (Duany 1994-1998) that bridges the gap from local to global by presenting neighborhood solutions that span from dense urban form to rural areas in an iterative but continuous manner, as illustrated in Figure 6.

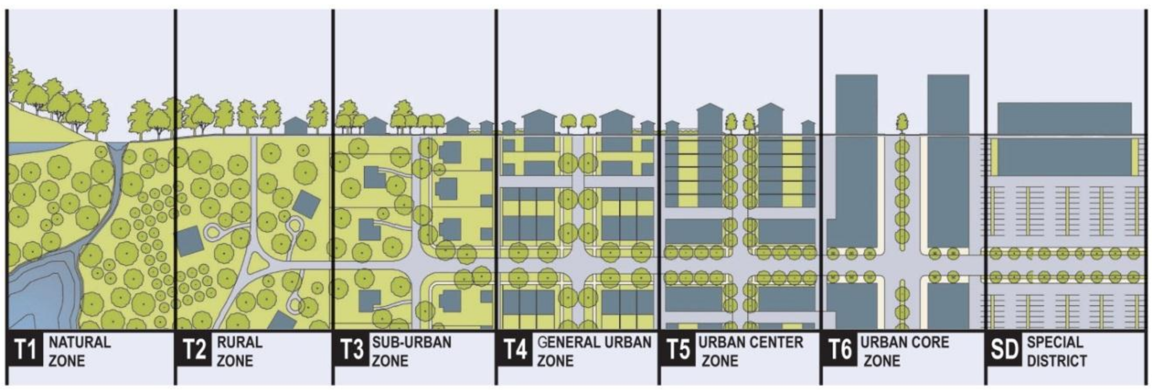

Figure 6. The transect as proposed by Duany Plater-Zyberk & Company. The transect diagram shows six normative Transect Zones (T-zones) used for the zoning of urban areas as well as natural lands. It is intended to be as general as possible in order to serve as a model for form-based codes. The elements are drawn in section at the horizon line and in plan below (source: Duany Plater-Zyberk & Company 2008).

The transect associates specific form-based codes to elements ranging from public space, to blocks, to buildings, to architectural, green building and landscape standards. For example, it specifies which building types are to lie along the transect, setback and frontage designs, thoroughfare street types and parking locations. Specific guidelines are assigned to each zone. They are alternative to zoning by regulating relationships between building, street and block designs. In new urbanism, "zones" take on a different form, but remain essentially zones in that they create homogeneity within themselves.

Form-based codes further respond to existing conditions by supplying guidelines to subdivide blocks that are too large. The block size and shape recommended by the new urbanists Moule and Polyzoides (1994) is a rectangular block 76 meters wide and 183 meters long. Form-based codes revise the dimensions and advocate for blocks no longer than 152 meters or with a perimeter smaller than 488 meters. For existing conditions with blocks larger than 0.8 hectares, the land would be subdivided by introducing streets first, then parcels and finally buildings that must all face a street (Parolek, Parolek et al. 2008).

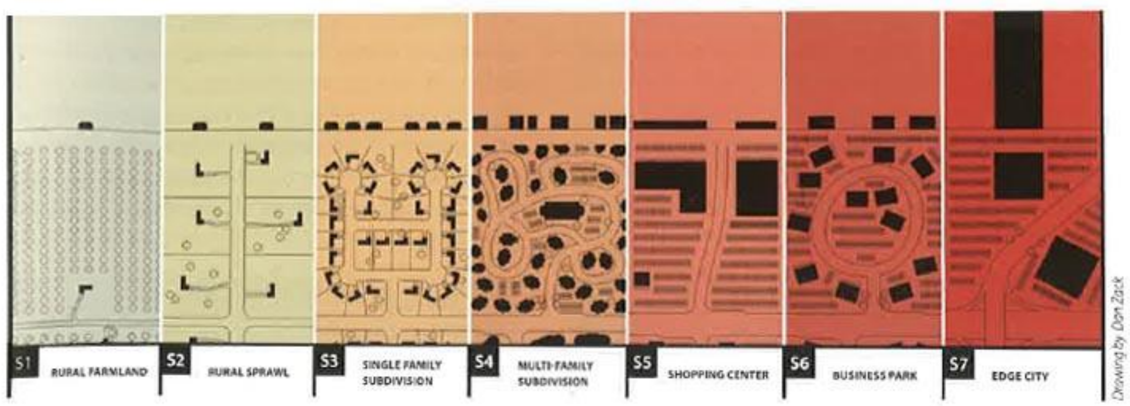

Figure 7. Sprawl patterns and configurations with rural farmland, rural sprawl, single-family subdivisions, shopping centers, business parks and edge cities (source: Tachieva 2010).

"Infill" (Calthorpe 1993) or "retrofitting" the existing city (Dunham-Jones and Williamson 2009; Tachieva 2010) aim at revitalizing, rescaling and repairing existing conditions. Proposals for suburban retrofits often aim at a compact and dense form. However, the existing conditions of sprawling cities have little direct correlation with the densities and the configurations of the transect (Tachieva 2010) (Figure 7). The process of transformation from the existing to the projected requires radical transformations. The question becomes one of where to introduce densities. One of the answers advocated by proponents of the compact city is densification at the edge of the block that aims at reconnecting buildings to the street. However, any intervention should be preceded by assessment of the potential inherent to the existing urban form.

2.1.3 Normative questions

The European model of the city defines public space within a framework of high building density and relatively small, typically compact blocks. Similarly, the pre 1920s city in the United States is characterized by street grids defining relative small urban blocks. Is it possible to implement the traditional model of the compact city in the areas of sprawl? The scale of sprawl is so large that increasing density to approximate that of the traditional city would require a massive infill of buildings that are non-sustainable.

Form-based codes have reintroduced the block as a relevant unit within guidelines, an indication of increased recognition of the block as key to structuring and limiting city growth. However, a first issue is recognizing the size range of existing blocks, from the superblock type, which encompasses blocks more than a kilometer wide, to the most compact building-block, which are less than 50 meters wide. These dimensions are at the extremes of the spectrum, but design proposals in the US need to be prepared to engage the extreme diversity of the current situation.

Form-based codes generally specify diagrams and street sections with specific dimensions and configurations. The decision as to what form and size is more appropriate depends on the properties of certain configurations and dimensions of streets, blocks, buildings and open space. However, despite the importance of these properties to form-based codes, there remains the question of how to best measure and assess the existing urban fabric. The assessment of the existing conditions is critical to the ability to evaluate future potential.

Retrofitting the existing city is a first step to transform sprawling cities into denser cities. However, it is problematic when attempts at densification insert fully designed neighborhoods into the existing fabric without first understanding the dynamic of the city. Such an approach is prone toward generating enclaves. The transect is a zoning system that attempts to address the city as a whole, but the ideals of the transect are not, in themselves, sufficient to address currently fragmented environments dominated by large irregular blocks. A better understanding of the interaction between the interior of the block and the block-face – the question addressed in this thesis – can facilitate the application of the ideals of transect zoning to existing conditions, particularly in conjunction with subdivision codes. To understand existing measures of urban form characteristics, the following section looks at empirical studies that have focused on blocks, streets and buildings relationships.

2.2 The study of urban form

In general, urban morphology addresses the forms and relationships of existing urban layouts, taking the street, the urban block, the plot and the building as elementary units of analysis. Martin and March (1972) have sought to provide urban morphology with a more explicit theoretical footing by systematically describing a field of possibilities rather than specific conditions and sites. They show that urban from can be studied independently of culture, economy, history or political aspects of the city by studying the mathematical relationships between those characteristics of form which affect generic functions: for example building depth and height, and plot ratios. By exploring different typological arrangements, such as perimeter blocks or courtyard forms versus free standing centrally located towers or pavilions, they have systematically compared how a given building density can occupy a site, and the implications of each alternative for land coverage, effective access, the creation of open spaces and the possibility of good daylight. Identifying the key dimensions that limit the viability of each alternative is critical to their enterprise.

Here, some empirical studies are reviewed to provide evidence for the feasibility of studying urban form in and of itself and the usefulness of such study. These studies focus on the block (size, dimensions, and density), the street (local and global connectivity) and the building (typology and land-use). However, in most cases the generalizability of findings is limited by the range of block sizes and degrees of shape irregularity considered. The review concludes by proposing the block-face as a primary morphological unit because it links buildings to streets. The block-face bridges the gap between the overall street layout dynamic (connectivity and circulation) and the buildings configurations required by specific functions (program and land use).

2.2.1 Urban morphology

Urban morphology,[4] as a discipline, provides techniques for measuring urban layout, as well as a corpus of empirical studies that demonstrate the interdependence of the block, street and buildings. In general, morphological methods lead to the establishment of morphological periods and clarify typological processes. Morphological periods are differentiated by the layering of history that determines "design areas" sharing formal characteristics. The characteristics are based on similarities and differences of streets layout, plot patterns and dimensions (Conzen 1960). New buildings types are viewed "*as products of a process of learning from the adaptations of a previous building type*" (Whitehand 2001) and links between past changes and the present state are identified. Urban morphology argues that the continuous evolution of societies is legible in urban form. Economic cycles or human interventions leave their mark on the material fabric of the city. For example, Whitehand looks at fringe belts (1967) as a morphological region with common characteristics that are highly distinct from the homogeneous and relatively stable Central Business District. Fringe belts were created at a specific time with a specific purpose in mind. They are recognizable by their large, irregular blocks and their variety of land uses. They are also limited in their capacity to accommodate changes. The larger and more irregular parcels are distinguished from more traditional forms for affecting the potential variety of future designs. The classification and typological

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[4] The International Seminar On Urban Form (ISUF) is the major conference for urban morphology and "Urban Morphology", edited by Jeremy Whitehand, published select conference papers and other peer-reviewed research.

characterization of urban form can help decision-making by identifying the universe of application of particular policies and regulations.

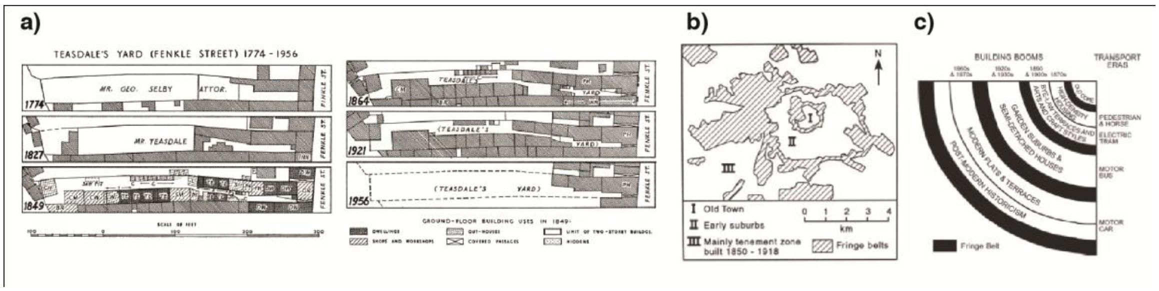

Figure 8. a) Survey over time of a street recording patterns of land-use and parcels in the city of Alnwick (source: Conzen M.G.R. 1960); b) definition of morphological zones based on historical changes in London, and c) diagram of fringe-belt locations over time (source: Whitehand 1967)

However, there are no cohesive and systematic reports of generalizable findings of traditional morphological research. While the methods are general, the findings accumulate as a library of case studies. The reliance on “zones” is also limiting, and the boundaries that define a zone are not always clear.

2.2.2 Theoretical configurations

Looking at American cities, Martin (1972) notes that the layering of history is not always the means by which urban form is generated and that artificial grids of streets are sometimes laid out before anything else. This is exemplified in the street grids of Manhattan, Chicago and San Francisco. Street layouts designed ahead of knowing or even anticipating any particular land use demonstrate that urban street layouts can, if appropriately dimensioned and configured, accommodate open ended future developments. This capacity may ultimately derive from the very simple elements of urban form. Organic or pre-conceived cities *“are built-up ultimately from a range of fairly* *simple formal situations: the grid of streets, the plots which this pattern creates and the building arrangements that are placed on these. The whole pattern of social behaviour has been elaborated within a limited number of arrangements of this kind and this is true of the organic as well as the constructed town"* (Martin 1972).

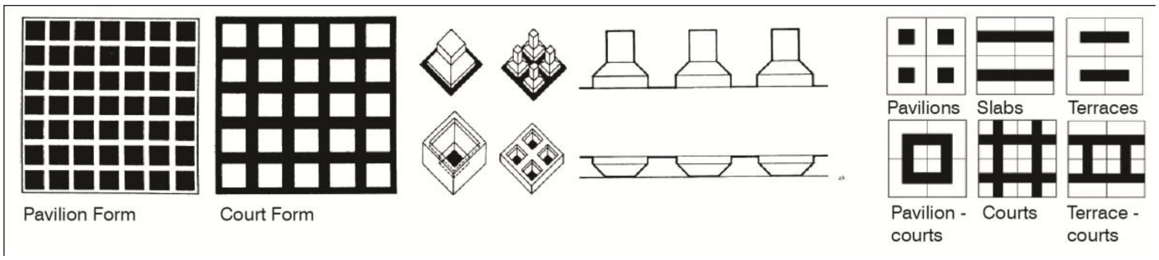

Figure 9. Two urban patterns of the same built density with very distinctive building configurations: the court type, which is a more traditional configuration, and the pavilion type, which approximates the modernist tower (source: Martin 1972). Generic urban forms, based on Martin and March (source: March and Trace 1968)

Based on these observations, Martin and March propose theoretical urban configurations or archetypical forms: the pavilion form (or isolated structure) and the court form, as mentioned earlier. In Figure 9, the pavilion and the court form have the same density on the ground but have very distinct configurations. Such diagrams show the limitation of density in characterizing urban form and, simultaneously, the importance of configuration. The generic forms are simple and repeatable. They eliminate the complexities of actual urban settings, thus allowing a systematic approach to compare geometries. A mathematical classification can distinguish designs that are structurally and formally different. These theoretical configurations open new possibilities, but need to be tested against functional performance and physical constraints that arise from the environment in order to be meaningful.

2.2.3 Empirical evidence

Empirical studies have addressed the dimensions, shapes and configurations of urban blocks as they interact with building footprints. At the outset, one can distinguish between advocacies of compact blocks and large blocks. A distinction exists between the findings and methods in studies of the traditional city versus the more irregular one. Arguments for small blocks are presented in the interests of promoting a compact city, usually based on a study of traditional urban patterns (Jenks, Burton et al. 1996; Scoffham and Marat-Mendes 2000). Other studies have shown that compact cities might not be the most desirable type of planning for cultural and economic reasons (Gordon and Richardson 1997). This thesis argues that the choice of compact blocks needs to be evaluated in terms of their potential and limitations for accommodating building types and configurations, as well as their behavior in urban settings (street connectivity). For example, morphological studies have shown that large blocks have the tendency to develop an internal system of routes (Moudon 1989; Siksna 1997), passages (Brown and Johnson 1985), or private streets (Maitland 1985; Jiang 2010) to access the center of the block. There is a difference however between these types of internal streets. Internal streets in a dense urban pattern designed for pedestrian access to the heart of the block, like passages, do not have the same impact as internal streets designed to access by the car the center of a block, like in shopping malls. This difference is due mainly to the size and density of blocks.

2.2.4 Historical and regular blocks

The size and the density of blocks is the subject of study that looks at the impact of dimensions on the transformation of urban blocks through time, but also the impact on street life. For example, according to Jane Jacobs (1961), short blocks afford more turns and therefore more opportunities for exploration of new routes between a given pair of origin and destination. She argues that the 243m (800‘) length of blocks in New York is too long and isolates pedestrians from adjacent blocks.

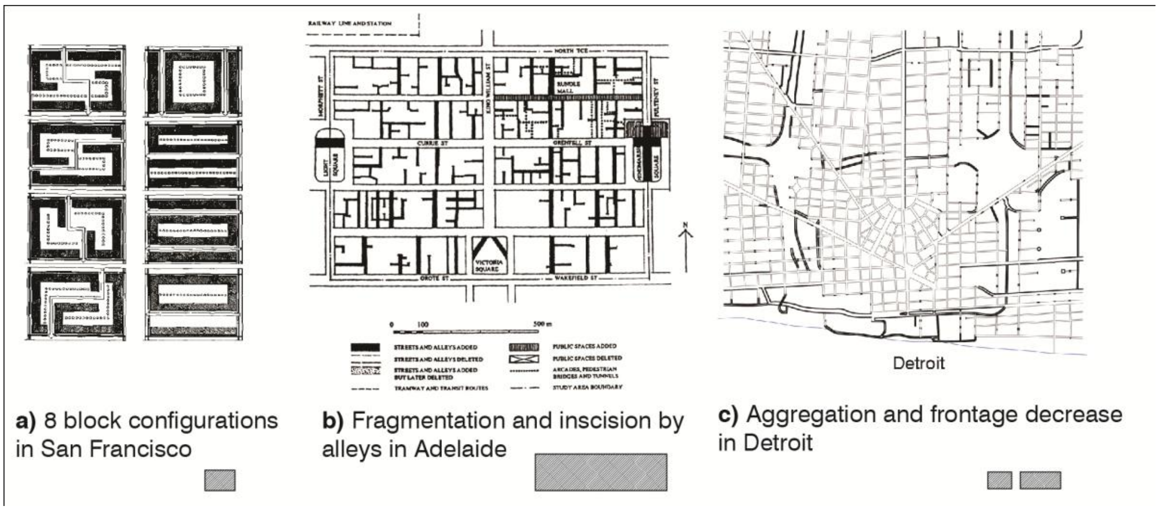

Figure 10. a) Eight configurations for buildings and alleys in a block of 84 by 126m in San Francisco. b) Subdivision of large blocks 154 by 554m with creation of internal access road in rectangular blocks of Adelaide, Australia (source: Siksna 1997). c) Diminution of block frontage without changing the surface of block by aggregation of blocks approximating 70 by 100-170m in Detroit, Michigan (source: Ryan 2008).

In San Francisco, the fragmentation of the urban block in half and the presence of service alleys within blocks show evidence of links between shape, size and building accessibility (Moudon 1989). Based on these observations, Anne Vernez Moudon created eight theoretical block configurations according to the location of building footprints and alleys (Figure 10-a). A comparison of Northern American and Australian cities (Siksna 1997) concludes that rectangular blocks allow more block area in proportion to street spaces and maximize developable land, while square blocks maximize circulation space. Siksna demonstrates the capacity of the urban structure to adapt to change. As part of this process, large urban blocks tend to fragment until an optimum size is reached; one that provides the right amount of frontage to support denser urban centers (Figure 10-b). A study of downtown Detroit (Ryan 2008) shows evidence that increases in block size do not necessarily increase the amount of frontage (Figure 10-c) and that small blocks will aggregate to accommodate different land uses that require large buildings or multiple buildings.

The diversity of building configurations within a block is captured in a matrix called 'spacemate', developed by Berghauser Pont and Haupt (2002), that associates block area, open space area, ground floor area and total floor area with different types of developments[5] (Figure 11).

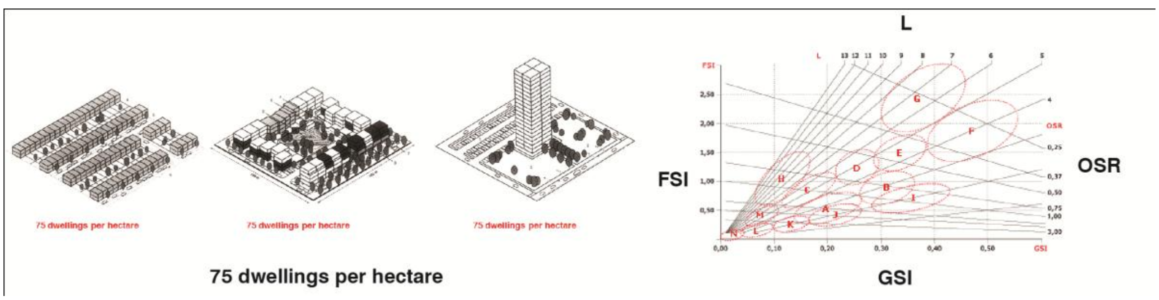

Figure 11. Three building configurations for a block with the same density of dwelling and the 'spacemate' matrix based on the correlation between floor space Index (total floor area/ block area), ground space Index (ground floor area/ block area), open space ratio (open space area/total floor area) and layers (total floor area/ground floor area). The letters represent different types of developments and their relationship to these ratios (source: Berghauser Pont and Haupt, 2002).

This classification is tested on building configurations from the Netherlands. It establishes a strong relationship between block dimensions and building configurations

[5] The studies distinguishes: low-rise spacious strip developments, low-rise compact strip developments, mid-rise open building blocks, mid-rise spacious building blocks, mid-rise closed building blocks, mid-rise compact building blocks, mid-rise super blocks, and high-rise developments.

(Berghauser Pont and Haupt 2010) as well as building functions. The area of the street is considered as part of the non-built space and is not strongly integrated into the space matrix. Spacemate provides a good representation of the European urban structure, where the majority of the urban area is located in the center of the matrix. North American cities are dealing essentially with the lower corner of the graph at right in Figure 11, with a predominantly sparse development pattern characterized by low buildings.

2.2.5 Big and Irregular blocks

Edge cities, urban fringe, fringe belts and suburbia are the topics of similar studies. Because edge city street layouts are mostly irregular, development patterns face different issues. A key issue is the separation of local and global connectivity. Another key issue is the fact that building configurations, and sometimes even street configurations, depend upon the prior zoning of land use. Both issues impact accessibility.

Marshall (2005) discusses the formative role of streets and street layout in structuring the designed urban setting. For him, urban structure, in its physical sense, is significantly influenced by the structure of movement and access. *"The urban street has traditionally united three physical roles: that of circulation route, that of public space and that of built frontage*" (Marshall 2005). On the urban fringe, there is a shift from open and interconnected street patterns to a closed and discontinuous street layout (Southworth and Owens 1993). Such a network disconnects neighborhoods from their surroundings and thus decreases pedestrian accessibility. Southworth and Owen's study of urban edge associates street patterns to block sizes (number of blocks) and degree of connectivity (number of intersections) and accessibility (number of access points) from the surroundings (Figure 12). They conclude with a discussion on the limitations of the disconnected street layouts in accommodating for change.

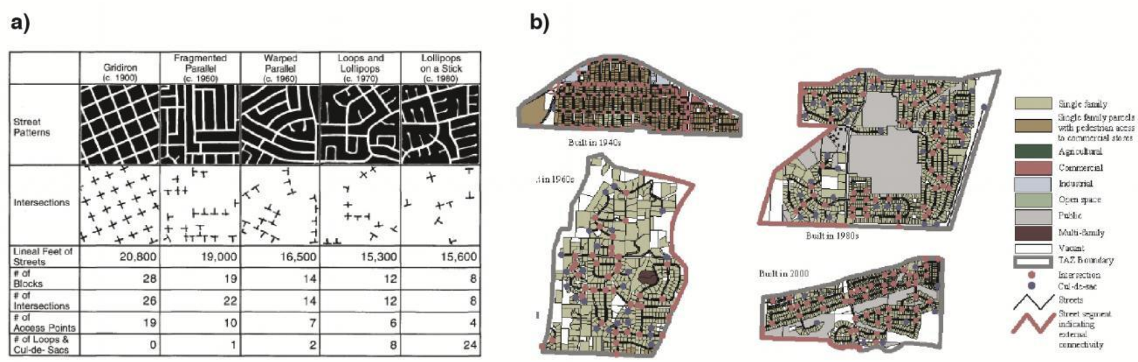

Figure 12. a) Comparative analysis of neighborhood street patterns (source: Southworth and Owens 1993). b) Distinction between internal and external connectivity of neighborhoods in Portland built from 1940's to 2000's (source: Song and Knaap 2005)

To better understand the implications of sprawl, Song and Knaap (2004) developed measures of urban form at the neighborhood level that distinguish internal and external connectivity. The internal connectivity of a neighborhood varies with street intersections, the amount of block perimeter, the density of housing per block, and the length of cul-de-sacs, while external connectivity was measured by the distance from ingress/aggress (Figure 12). They criticize the urban blocks that are too large to promote connectivity. In this study, the distinction between local connectivity and global accessibility requires a pre-defined neighborhood boundary.

Accessibility is often driven by building location, but also by the size of buildings. The size and configuration of commercial buildings on the blocks have an impact on the urban fabric and have transformed it. A study by Brenda Scheer and Mintcho Petkov

(1998) compares commercial centers as they develop in regular and small gridiron plans to ones located in edge cities (Figure 13).

Figure 13. Maps of Edge cities and traditional cities at the same scale showing the range of differences in building size and density for commercial centers (source: Scheer and Petkov 1998)

From the range of block sizes, they observe that large blocks tend to disengage the building form the street. This disconnection of the building from the street is present in blocks that accommodate large shopping malls. The block, while globally connected, is locally disconnected from its surroundings. Maitland argues that the disconnection comes from the inverted nature of the shopping mall. This building type carries its frontage inside, not on the edge of the block. Figure 14 illustrates the implementation of a shopping mall in a traditional block and the inversion of frontage that occurs (a) as well as a shopping mall outside the city between a networks of highways (b). On the traditional block, despite the location of the primary frontage inside the block, there is still a connection to the surroundings. The scale of the shopping mall connected with highways allows only very circumscribed pedestrian access. The building generates pedestrian routes, but disconnects connections to its surroundings.

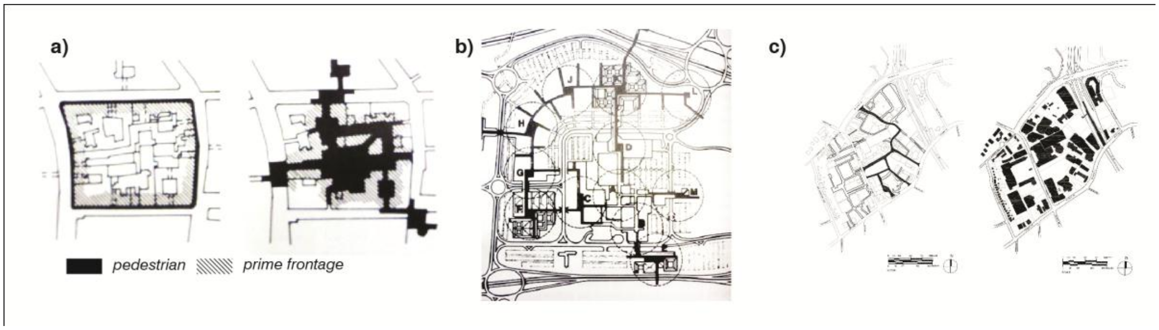

Figure 14. a) A traditional block with buildings facing the surrounding street and after the construction of a shopping center with internal frontage, and b) a shopping mall on a large block surrounded by highways (source: Maitland 1985). c) Evolution of a block accessibility and connectivity after construction of 3 office towers and their access internal streets (source: Jiang 2010).

"Tower place block" in Buckhead, an Atlanta neighborhood, exemplifies the building as the generator of the street network (Jiang 2010). The evolution from a traditional residential neighborhood to a mix-used superblock occurs regardless of the surroundings (Figure 14-c). To accommodate large building footprints, there is a consolidation of parcels. Traditional narrow and rectangular parcels bounded on one side by an edge street are replaced by larger, more compact parcels, which do not necessarily have direct access from the edge street. Parcels are wider and located in the center of the block. The notion of urban front is replaced by that of "front address". The problem of access is solved by the creation of private roads.

These studies show examples of situations where investments in buildings act as drivers of urban form. It shows how the location of buildings within a block impact accessibility and connectivity locally and globally. The impact differs with the scale of the setting, as shown by Maitland's comparisons of shopping center developed in traditional blocks and in superblocks.

2.3 Discussion

These studies show that small and regular blocks are more resilient over time, accommodating a variety of land uses while preserving the stability of the street layout. There is a general consensus on the superiority of regular and small blocks for higher building densities. Blocks that are very large create incisions and fragmentation; therefore they are less connected, have less (external) frontage and tend to dissociate the building from the street (e.g., by developing internal frontage). But the last set of studies underscores the radical difference between regular and small versus irregular and very large blocks and the ensuing difficulty of comparing them according to meaningful measures. Studies of the configuration of sprawl show the inconsistency between our understanding of irregular forms and the tools proposed to measure it (Scheer 2001). Furthermore, a study that compared the urban form of Barcelona and Atlanta, has shown that what is relevant for a regular and dense city cannot be applied to a sprawling city (Bertaud 2004).

The development of better analytical descriptions of what exists is therefore necessary so as to be able to build within the contemporary metropolitan city of North America rather than against it. More particularly, the potential of sites to accommodate future development has to be assessed in terms of the balance between local and global access, as determined by the conditions at the perimeter of the block, and available land as determined by block size, shape and existing building footprints. The block-face emerges as the morphological element that naturally associates the properties of the street network and the properties of buildings. This research develops a method to assess urban layout that can capture variations locally and globally and that is not based on pre-defined zones. The block-face is the element that belongs to both the street and the building and, as such, can capture variations along a street or between different faces of a block. By looking for systematic relationships between buildings and streets, there is a clearer understanding on how they associate or dissociate. As such they can affect the future of cities by limiting the potential forms of future development.

CHAPTER 3

UNIT DEFINITION AND DATA REPRESENTATION

It is challenging to express theoretical ideas using data. One must be aware of the preconceived notions embedded in representations, as well as of the potential of a dataset for clarifying and testing theoretical ideas. The selection of the city and the data collection are undertaken following two main criteria: representativeness of a variety of urban forms, including regular and irregular forms, and the availability of data at levels of detail or resolution that are appropriate to the development of the theoretical ideas under consideration.

The historical background of the city of Atlanta is provided first, emphasizing the characteristics that make this city a good case-study for the purposes of this dissertation. Second, the morphological units discussed in the previous chapter – block, street and building – are analyzed and visualized within a Geographic Information System platform. Representation in GIS entails a certain level of abstraction and consistency for the data and the handling of theoretical questions: streets are represented as lines rather than 2D elements, and blocks are represented as polygons.

The chapter concludes with a definition of block-face in analytical terms that are clearly expressed in GIS. The definition takes into account theoretical considerations pertaining to the nature of block-faces and calls into question preconceived ideas about the relationship between blocks and block-faces.

3.1 From grids to sprawl: Atlanta, “the city in a forest”

The choice of Atlanta as a case study is not arbitrary and is fundamentally linked to the debate regarding the relative merits of compact and sprawling urban forms. In most studies on sprawl in the US, Atlanta ranks as the most sprawling city. At the same time, it has a relatively dense historic core. By selecting a single extreme case, which includes such a variety of conditions within it, the study aspires to address a range of conditions found elsewhere in a relatively economical fashion. The dissertation posits that if measures can be defined and that account for the variety of conditions found in Atlanta, the method can be applied to most cities in the US. This attention on the adaptability of measures distinguishes this study from studies focusing on traditional, regular or compact cities. Atlanta is not designed at a pedestrian-friendly scale, but rather at the scale of transportation, mostly, but not exclusively, by private automobiles. As a result, it is comprised of patches of urbanism that have developed locally following their own logic while maintaining links to the global structure according to a very different logic. This phenomenon can be discussed in terms of local centers versus global structures. Castell’s (1996) dictum that “*It is this distinctive feature of being globally connected and locally disconnected, physically and socially, that makes megacities a new urban form. A form that is characterized by the functional linkages it establishes across vast expanses of territory, yet with a great deal of discontinuity in land use patterns*” resonates with conditions found in Atlanta where local and global connectivity are often at odds. This impacts the location of buildings and the distributions of land-use.

3.1.1 History of transportation

Atlanta's history is closely linked to transportation in a way that is reflected in its urban structure, first with the railroad, then with the airport and its worldwide connections, and finally with its system of highways. Modes of transportation have molded the city and created heterogeneous conditions. The focus on transportation has often damaged, if not obliterated, the pedestrian scale in many places, even as pedestrian friendly street segments can be observed in historical neighborhoods.

The City of Atlanta was founded in 1837 as "Terminus" and was renamed "Atlanta" in 1847. The first settlement was established around the crossing of railroads linking Savannah and Augusta to the Midwest. Atlanta was incorporated as a city in 1845 and became the state capital of Georgia in 1868. Atlanta is a city of the 20th century that carries very few features of past urbanism in its building stock due both to natural hazards, such as the fire that destroyed the old fourth ward neighborhood in 1917, and the proclivities of private development. Such events impacted not only the building stock, but the street structure as well (see appendix C "Fulton County Building stock- year built).

The first flight from the Atlanta airport was in 1926. By the 1930s, the airport had developed into one of the busiest airports of the country and is considered today to be one the busiest airports in the world. The preeminence of the airport helped turn Atlanta into an economic hub for the south. In the 1950s, Atlanta constructed a highly comprehensive system of highways that gave rise to the expansions of the city into suburbs. The city is bounded by the interstate 285, known as the "perimeter". Three major interstates – I-75 (northwest-southeast), I-20 (east-west) and I-85 (northeast-southwest) –

intersect at the "connector", a merged section of I-75 and I-85 that splits the city into two parts, east and west (Figure 15-c). Overall, the metropolitan Atlanta area is fed by 13 highways. In 2008, it ranked highly for air pollution, traffic congestion, and long commuting times by Forbes[6]. The impact of commuting is immense: the population experiences of 62 percent surge each workday when area residents commute in[7]. Figure 15 illustrates the city of Atlanta, in its statutory definition, in relation to other boundary systems, official and unofficial. The Metropolitan Area (Figure 15-a) encompasses the largest area and a large amount of non-urban land; the City of Atlanta overlaps two counties (Figure 15-b), and, finally, the highway 285 boundary or "perimeter", which dominates the cognitive map (Figure 15-c). The sample for this study was derived from the City of Atlanta.

There is no major natural barrier such as river, mountain, preserved land, that acts as a constraint on the growth of the city. The growth in the city's population has undergone a trajectory of continuous increase. Between 1990 and 2000, the population increased by 5.7 percent, while the state of Georgia as a whole experienced a 26.4 percent increase, according to the 2000 Census (see appendix A for a timeline of population and growth). The total population of the metropolitan area is more than 5 million inhabitants in an area of 21,694 km^2 (8,376 square miles). Fulton County covers

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[6] "*No. 1: Atlanta*, Ga: *Here, in the fastest-growing city in America, more people flood the roadways than the infrastructure can handle. Commuters spend 60 hours a year stuck in traffic, second only to those in Los Angeles. If that weren't bad enough, Atlanta is so spread out that only 29% of drivers get to and from work in less than 20 minutes, the third worst rate in the country, and 13% spend more than an hour getting to work, the fourth worst rate in the country. The local train system doesn't service the entire city, and thus fails to relieve the pressure"*
http://www.forbes.com/2008/04/24/cities-commute-fuel-forbeslife-cx_mw_0424realestate.html

[7] Atlanta is ranking 18th in the top 101 of cities over 50,000 that people commute into. Atlanta has the largest positive percentage daily daytime population change due to commuting.
http://www.city-data.com/top2/toplists2.html

1,385 km^2 (534.61 square miles) and had a population of 920,581 inhabitants in 2010. The population density is 596 people per square kilometer (1,544 people per square mile).

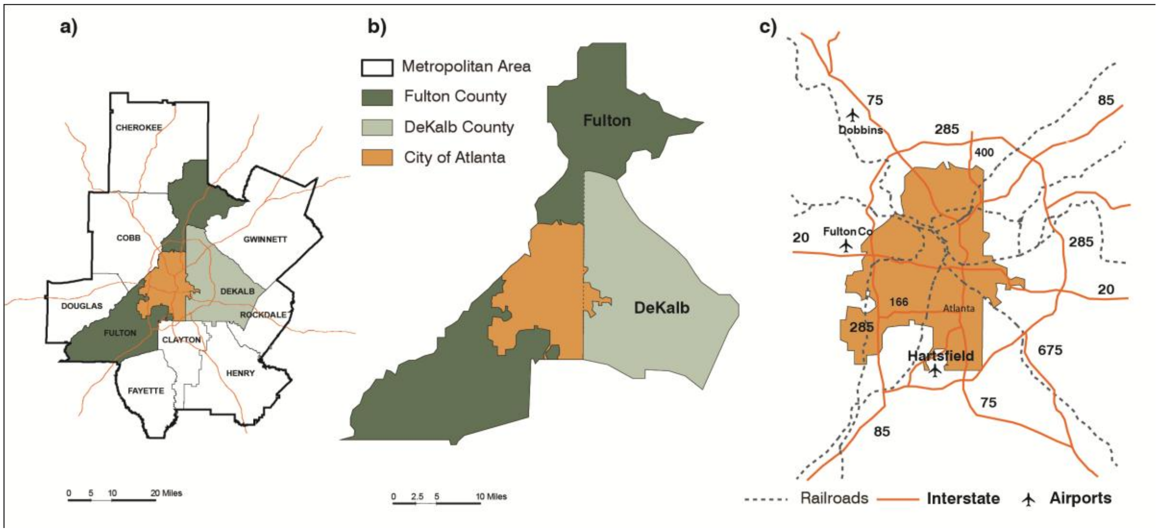

Figure 15. a) Maps of the city of Atlanta in relation to the metropolitan area. b) The two counties and the city of Atlanta. c) Locations of railroads, major highways and airports.

Overall, the City of Atlanta can be characterized as having a low-density form that relies heavily on the car. With a population that fluctuates widely on a daily basis and a dearth of historic buildings to preserve, Atlanta is a city that adapts to changes and succeeds relatively well at offering a variety of urban forms.

3.1.2 Diversity of neighborhoods

The city of Atlanta has a particular urbanism that results from lots of individual private developments. Atlanta officially recognizes 242 neighborhoods, which show a variety of forms, from traditional neighborhoods such as Virginia-Highland and Fairlie-

Poplar, to subdivisions such as Dunwoody or Sherwood Forest, to urban core areas like Downtown or Midtown, to institutional campuses such as Georgia Tech and complexes like the Peachtree Center. Neighborhood populations range from 500 to more than 15,000. There is a diversity of urban patterns, as shown in

Figure 16. Neighborhoods are consolidated in 24 larger Neighborhood Planning Units (NPU). The NPUs were created in 1975 by Atlanta mayor Maynard Jackson to involve communities in the decisions made for the city of Atlanta and to include citizen participation in local affairs (See appendix B for a map of NPU).

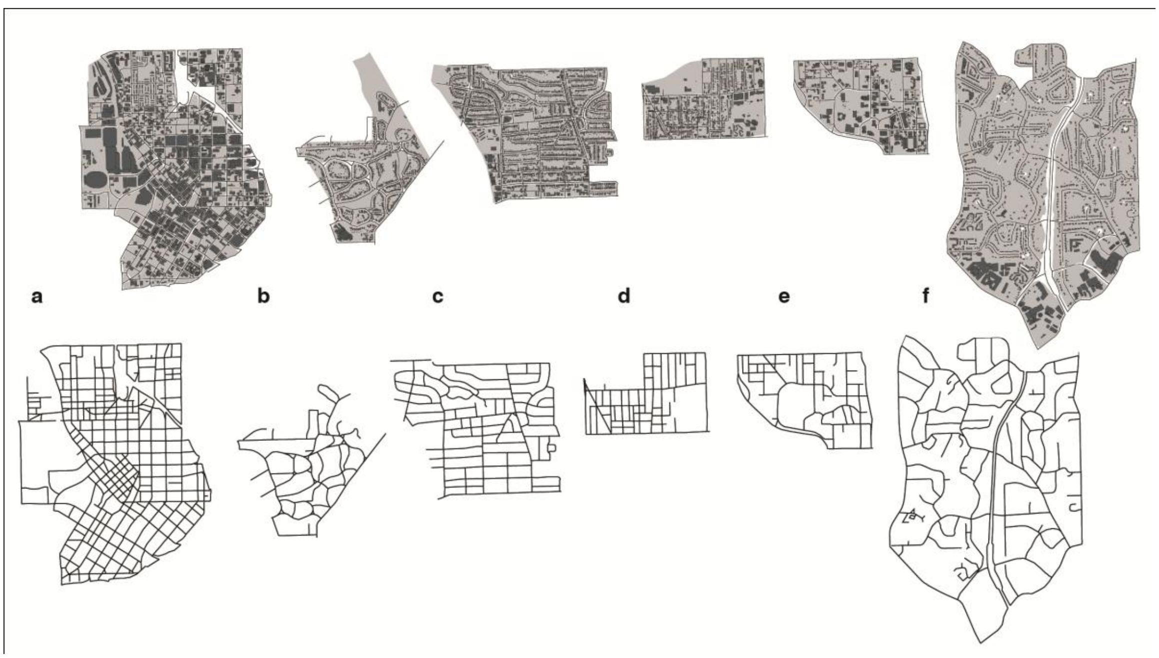

Figure 16. Different neighborhoods in Atlanta: a) downtown with its square grids, b) Ansley Park and the curvilinear streets, c) Virginia Highland with rectangular grid, d) Home park with small rectangular grid, e) Georgia Tech as a university bounded layout, f) North Buckhead with large blocks and irregular streets.

The diversity of these neighborhoods in terms of area and number of blocks is shown in Table 1, which compares downtown Atlanta with other neighborhoods as well as with the downtowns of major North American cities (Peponis, Allen et al. 2007). It shows Philadelphia with the densest downtown in terms of number of blocks per square kilometer with 134.23. It is followed by New-York City (95.37), San Francisco (83.16), Houston (80.05), Boston (76.95), Dallas (76.91) and Chicago (69.97). Downtown Atlanta is comparable to the downtowns of Detroit (60.04), Los Angeles (53.78), Miami (51.61), Washington DC (51.35), or to neighborhoods like Berkeley (45.88) or the Bronx (58.94).

Table 1. Comparison of neighborhoods in Atlanta with downtown of North-American cities by number of blocks by square kilometer (source: Peponis Allen et al. 2007)

	Total Area	# Block
ATLANTA		
Ansley Park	16.9	15.5
Brookhaven	18.3	9.15
Buckhead	15.8	10.2
Candler Park	12.9	21
Downtown	11.8	58.5
Fairburn	27.3	4.14
Virginia Highland	17	13.3
West End	13.4	23.9
BOSTON - Downtown	10.9	77
DALLAS - Downtown	10.2	70
CHICAGO - the Loop	12.8	76.9
DETROIT - Downtown	11.3	60
HOUSTON - Downtown	12.4	80.1
LOS ANGELES - Downtown	12.3	53.8
MIAMI - Downtown	9.12	55.6
PHILADELPHIA - Downtown	11.5	134
WASHINGTON DC - Downtown	12.2	51.4
SAN FRANCISCO - Downtown	10.6	83.2
Berkeley	12.7	45.9
NEW YORK - Downtown	10.4	95.4
Bronx	11.7	58.9

Neighborhoods in Atlanta range in this study from 4.14 in Fairburn to 58.47 in Downtown. Fairburn with an extremely low number of blocks per square kilometer is representative of extreme cases of sprawl and is no exception compared to other neighborhoods.

3.1.3 Extreme Sprawling city

The name of Atlanta is often associated with the one of “sprawl”. A ranking of the 20 most sprawling cities in the United States by the Sierra Club (1998) places Atlanta in first place[8]. In "Do Land-use controls cause sprawl?” Atlanta is the most sprawling city again with the exception of Milwaukee with a lower number of inhabitants per square mile (Pendall 2011). Galster, Hanson and their team developed a complex index that takes into account: density (number of resident units per square miles), continuity (degree to which dense urbanized areas create pattern sparse or continuous), concentration (spread of density), clustering (degree to which residential development are bunched together), centrality (distance of residential development to CBD), nuclearity (mono-nuclear or poly-nuclear patterns of development), mixed-use, and proximity (distance of Land uses with each other) (2001). In this study, Atlanta ranks first as the most sprawling city overall with the lowest density and concentration factors (Table 2). The study of sprawl index by Ewing Pendall and al. (2002) also shows Atlanta at the top list of sprawl. This study is based on the 83 largest metropolitans in the US (Table 2). The index is calculated by 4 factors: density (based on population), land use mix (activity and employment), degree of centering (density in relation to center), and street accessibility

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[8] source: http://www.sierraclub.org/sprawl/report98/cities.asp

(size of blocks). Streets are classified as either dense or sparse, interconnected or disconnected, straight or curved patterns. Sprawl is associated with "*sparse, discontinuous, curvilinear networks creating long, large blocks*." Ewing, Pendall and Chen did not expect the typology of streets to be a significant parameter defining sprawl, but they recognize that street typologies have a strong impact upon transportation and increase time of commute (2003).[9]

Table 2. Ranking of the 20 most sprawling cities (source: Sierra Club 1998), Ranking of 13 cities by sprawl factors (source: Galster, Hanson et al. 2001), index of sprawl measured by density, mix, centers and streets factors in 2000 (source: Ewing, Pendall, Chen 2002).

	ATLANTA	SAN FRANCISCO	NEW YORK	BOSTON	CHICAGO	DALLAS	DETROIT	HOUSTON	LOS ANGELES	MIAMI	PHILADELPHIA	WASHINGTON DC	DENVER
Sierra Club 1998													
Rank (20 most sprawling)	**1**	*NA*	*NA*	*NA*	10	15	11	*NA*	*NA*	18	*NA*	3	6
Galster, Hanson, Ratcliffe, Wolman, Coleman, Freihage 2001													
Density	**13**	5	1	10	4	12	9	11	2	3	6	8	7
Concentration	**13**	3	1	2	6	4	10	6	8	11	4	9	12
Clustering	11	12	3	6	4	5	10	1	**13**	8	2	6	8
Centrality	7	**13**	1	3	9	10	11	4	8	12	2	5	6
Nuclearity	10	5	1	3	4	12	6	**13**	9	11	2	8	7
Proximity	8	5	1	6	3	4	7	10	2	12	9	11	13
Total	62	43	8	20	30	47	53	45	42	57	25	47	53
Rank (13 cities)	**13**	6	**1**	3	3	8	10	7	5	12	2	8	10
Ewing, Pendall, Chen 2002													
Density Factor	85	155	243	114	143	100	97	95	152	129	115	107	104
Mix Factor	74	107	130	124	115	83	103	110	123	105	120	79	116
Centers Factor	82	129	145	109	86	81	63	87	72	93	96	98	109
Streets Factor	57	140	155	119	135	90	93	96	123	136	113	98	126
Overall INDEX	**58**	147	**177**	127	121	78	80	93	102	126	113	91	125

[9] The link between street layout and sprawl is of importance for later association between street layout measures and potential for compaction.

They conclude their review of precedent studies on sprawl by: "*With the exception of Atlanta, which always seems to rank as one of the worst, the different variables used to operationalize sprawl lead to very different results*." Sprawl is interesting if it is seen as an urban form that can still be changed. "The Sprawl Time Span" (Harvey and Clark 1965) presents sprawl as a stage towards urbanization (or compaction). It implies that the state of sprawl is not a permanent one and it will most likely change state. Therefore an attempt is made to distinguish forms of sprawl that have potential for compaction or urbanization from static forms.

It has been shown that Atlanta embeds a variety of urban forms that range from traditional urbanism with gridiron to extreme forms of sprawl. The local and global connectivity of the urban form are not always the same because of the range of urbanisms in Atlanta. Furthermore, Atlanta is made of urban forms that have not yet reached their full potential. In these currently sprawling patterns, future density and street connectivity can increase. Thus it is useful to determine how to measure their potential for transformation, and which physical characteristics are more conductive to changes in block subdivision and street connectivity.

3.2 Morphological Units in GIS

This section addresses the definition of the primary morphological units and elements of study; it also explores their relationships. The choice of the units results from the combination of the need to have disaggregated enough measures that can powerfully describe a phenomenon under consideration, and the limitation inherent to the

Geographical Information System [GIS] platform: mainly the access to data and their representation. The selection of the urban morphological units is open to debate (Levy 1999; Osmond 2010). Yet, the previous chapter has shown the relevance of the three primary units: street, block and buildings with the later addition of block-face. Their representation in the GIS form requires transformations of data that entail a certain level of abstraction, translation and interpretation.

3.2.1 GIS: Translation to geometry: 4 Layers (aggregation of data)

Geographical Information System (GIS) representations provide us with points, lines and polygons to describe cities graphically. Each of these elements is linked to data and the storage of data by graphic element allows one-to-one or one-to-many relationships (Berling-Wolff and Wu 2004). The ability to deal with one-to-many relationship is essential from the point of view of measuring the dynamism of a street system. U.S. Census TIGER (Topologically Integrated Geographic Encoding and Referencing system) street, parcels and buildings files serve as the main graphic databases. For the purpose of the study, information and graphic representations have been simplified. This is mainly due to lack of precision in the drawing of the GIS map. The map has three primary layers: street centerlines, parcels and buildings. They are transformed to assure the best precision in the data set. Figure 17 illustrates the different manipulation of the layers that led to the final basic four layers: road centerlines, blocks-centerline, block-parcels and aggregated building footprints. The top of the figure shows the starting three layers on the left (before) and on the right the four operational layers after transformation. Transformations are mainly aggregation of data.

The street layer, made of polylines, was cleaned to ensure that variables for road segments between intersections could be calculated. If on the map road segments overlapped parcels, streets were modified and not the parcels. Road centerlines define the boundaries of blocks-centerline, which are the closest equivalent of census blocks (Figure 17-b). Parcels did not match the building footprints; the pattern of multiple overlaps made it impossible to allocate buildings to parcels accurately enough. Consequently, both layers were transformed. Adjacent parcels polygons were consolidated into a single-polygon which is equivalent to a block (Figure 17-c). Building footprints were drawn on the map according to differences in heights. A building therefore could have several polygons; adjacent polygons then have been consolidated into a single polygon. These polygons represent aggregated building footprints (Figure 17-d).

A comparative study of downtown Savannah and Atlanta (Vialard 2012) has shown that plots are less permanent than blocks. Plots can be more easily aggregated or fragmented, at least in North American cities. The aggregation of parcels into blocks also includes alleys if these are not represented by a street centerline. The alleys which are not represented in the street centerline maps are mostly nameless back alleys. They are treated as very narrow and elongated parcels. Information associated with individual building and parcels is retained when possible. Although such information, for example the land use associated with a parcel, is not essential to this study, it might prove useful for future work. Because of these manipulations, two distinct layers are provided for blocks: the block-centerline layer and the block-parcel layer, blocks in the latter are smaller than the former (Figure 17-bc).

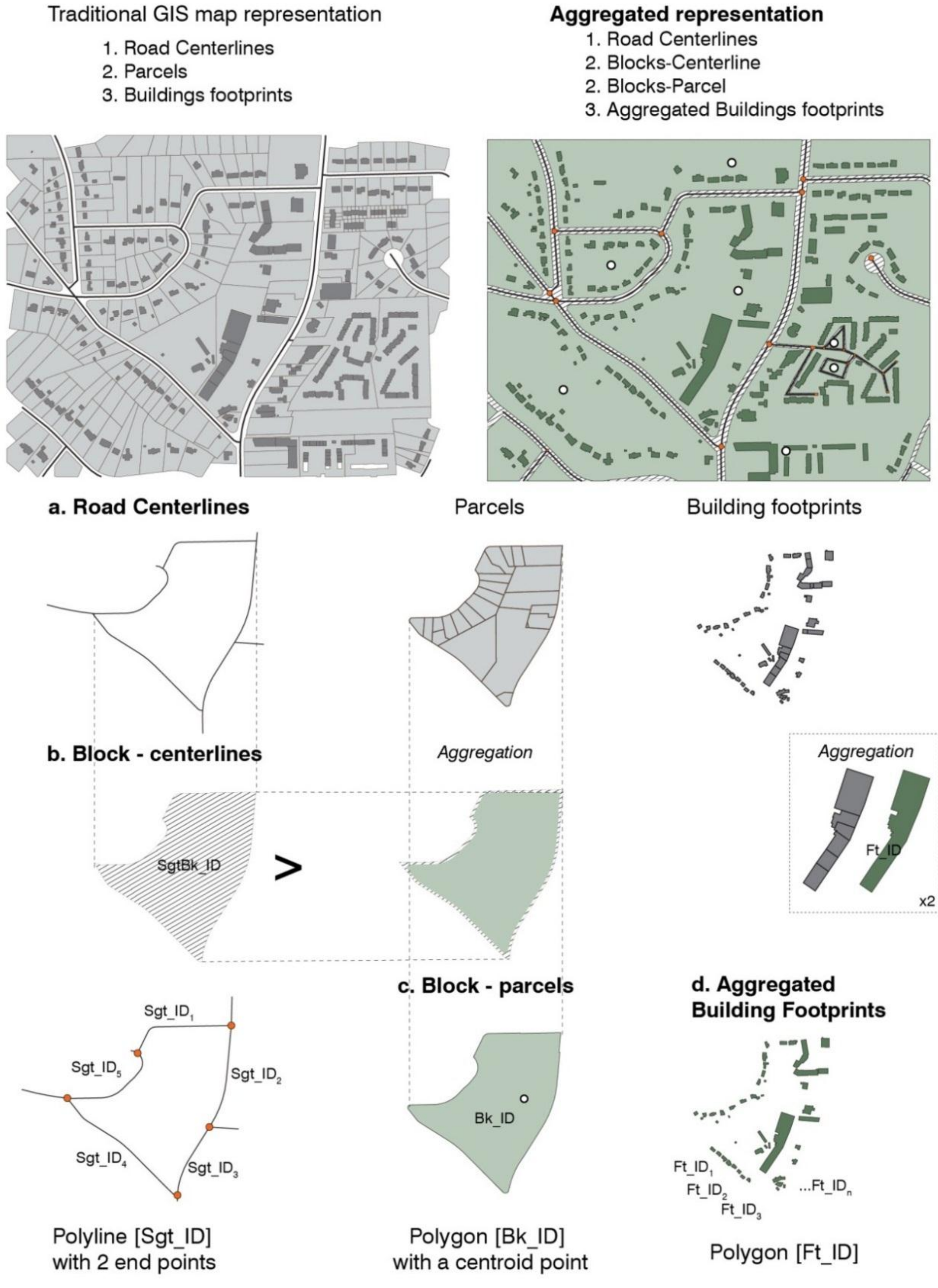

Figure 17. Traditional GIS representation and its aggregated representation: a) street centerlines, b) block-centerlines larger than c) block-parcels and d) aggregated building footprints.

3.2.2 Primary dimensions and units

Graphic data are polygons for blocks and buildings, and polylines for streets. A road segment is a line segment or series of smaller line segments that are combined to form a continuous string of lines between two intersections. Location is given by points such as centroid, mid-points or end-points. Polygons and polylines provide a measurable area or distance. Depending on the type of graphic, the numeric data associated with each element vary. Primary numeric data associated to a polygon are its perimeter and area which are calculated directly from the GIS representation. For a polyline, it is its length. Measures are in meters or square meters; other units of length or area are used when appropriate to the element size. The number of elements contained within an element or making the boundary of an element is recorded, as well as the sum of distances or areas of these elements. Apart from traditional dimensions, the following chapter presents more elaborated dimensions as well as measures of shape which are more appropriate to describe the building, block and street stocks of a city.

Data Summary

Table 3. Morphological units with their type of representation in GIS, their unit measure, their number and the type of dimensions associated to their representation.

Morphological Units		Type	units	n	Dimensions
Road segment	[Sgt]	. Polyline	Meters	13 603	. length . Perimeter
Block-centerlines	[SgtBk]	. Polygon . Polyline	Square meters Meters	3 770	. Area . Perimeter
Block-parcels	[Bk]	. Polygon . Polyline	Square meters Meters	4 028	. Area . Perimeter
Building Footprints	[Ft]	. Polygon . Polyline	Square meters Meters	108 455	. Area . Perimeter

* Centroid in GIS are calculated by ArcMap and is forced inside the polygon.

3.2.3 Exclusions and limitations

The city of Atlanta is made of Fulton and DeKalb county. Only a very small portion the city of Atlanta belongs to DeKalb County, approximately 10 percent; the majority of its land is located in Fulton. For ease of database collection, the sample only encompasses the part located within the Fulton County boundary. The assumption is that the 10 percent located on the east is very similar to the west part of town (Figure 18).

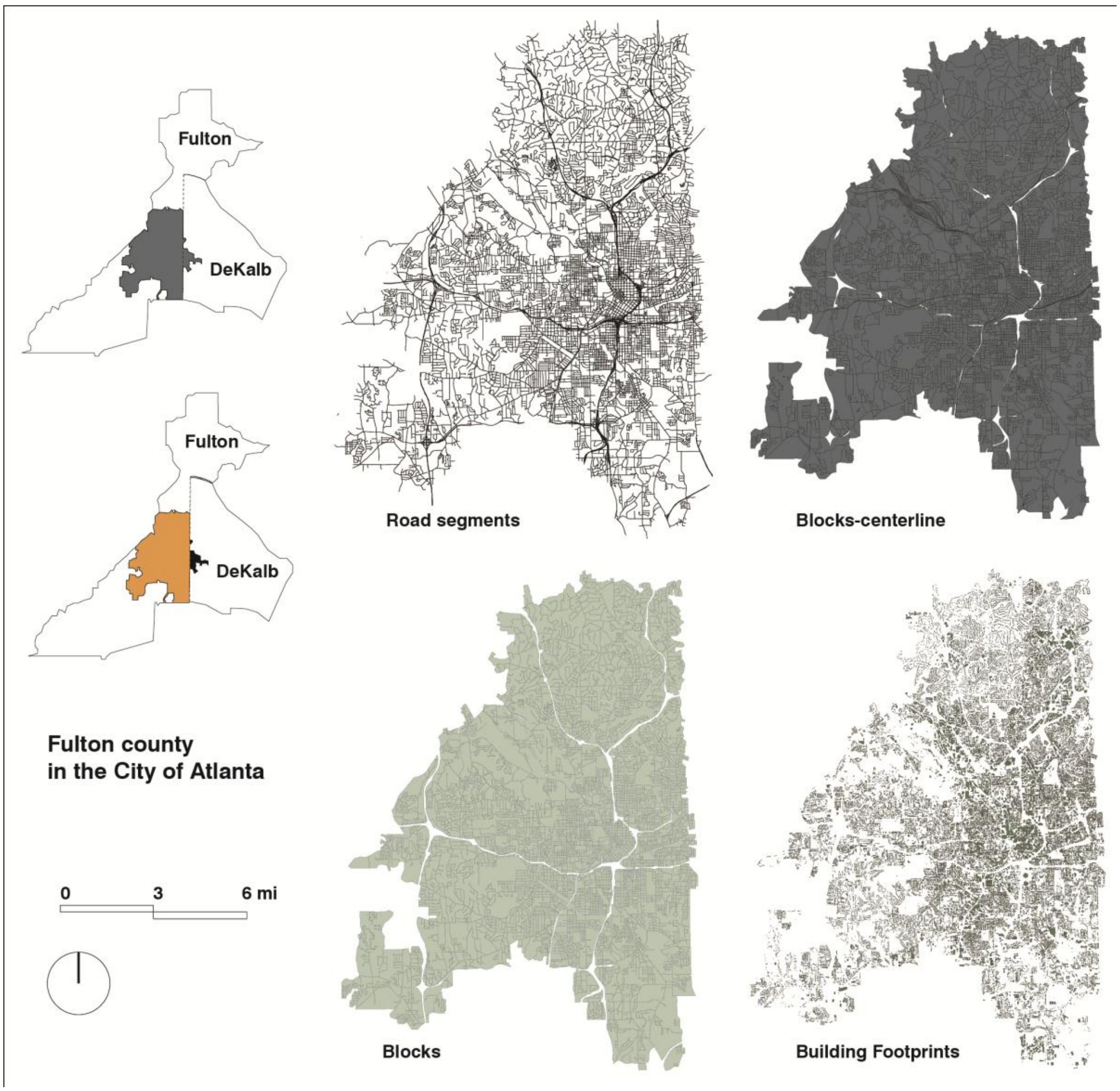

Figure 18. Map of Fulton county within the city limit of Atlanta: street centerlines, blocks-centerline, blocks made of aggregated parcels and aggregated building footprints.

Exclusions

Street segments located outside the sample are removed from the original data, as well as street segments that are not in "direct" contact with any block (between highway). Some blocks were excluded from the sample. The county boundary is located on the edge of parcels, not on the edge of blocks. If blocks were not fully included within the city limit they were removed. If the definition of block is "a portion of land surrounded by streets", then blocks that did not fit that definition are removed, as well as the blocks that were isolated from the sample. As explained previously, only the set of primary units are selected: street, block-centerlines, block and building footprints and the plot is disregarded. The representation in GIS Platform excluded the volume of building, although height could be added as a numeric data and not graphically represented. Aggregated building footprints smaller than 12 square meters (130 sf), which is the size a single room, were excluded.

Limitations

Some issues need discussion relative to the definition of block boundaries by some of the elements mentioned in the census track definition: "*Census blocks, the smallest geographic area for which the Bureau of the Census collects and tabulates decennial census data, are formed by streets, roads, railroads, streams and other bodies of water, other visible physical and cultural features, and the legal boundaries shown on Census Bureau maps*."[10] The non-inclusion of railroad, steams and bodies of water affect the accuracy of what part of land is accessible.

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[10] http://www.census.gov/geo/www/GARM/Ch11GARM.pdf

Different aspects are in balance: if railroads are included, they provide a more accurate account of different conditions along the block boundary. But can they be considered as block-face? They do not carry the “accessibility” of the other block-faces (Figure 19-b). Same concerns apply to river and steams. Railroad and rivers are hard boundaries that cannot be crossed easily. The question is how they should be accounted for in the definition of a block: they are “dead” edges without frontage or connectivity. Even though they are important when it comes to describing and comparing block-face differentiation, they are disregarded from this analysis because they do not participate to the connectivity tissue of the city. A railway line is not treated a dividing the blocks its crosses. Future work however, could revisit this issue.

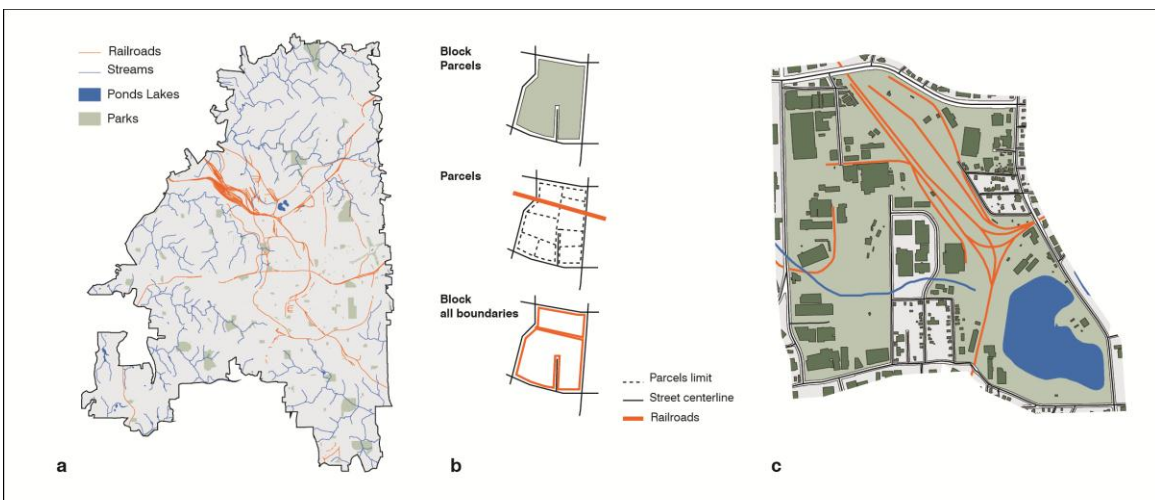


Figure 19. a) GIS layers for railroads (lines), Lakes & Ponds (polygons), Streams & Rivers (lines) and Parks (polygons) for the city of Atlanta ; b) theoretical example of how railroads can change the block boundary and c) example of a block with river, pond and railroads that limit the location of building footprints, and where the pond could be perceived as a building footprint.

A similar issue arises as whether or not to include lakes and ponds as inaccessible footprints. They are excluded from this data set because lakes and ponds are occupying a very small amount of land. Parks, however, are accessible areas. Land use is available at the parcel level. When parcels are consolidated into blocks, the land use category is transferred onto the block.

3.3 Block-face: GIS definition

Block-face as morphological unit has been used in only few urban morphological studies (Purciel, Neckerman et al. 2009). The most common urban element used is the block. The distinction between collecting data at the block level or the block-face is that the latter includes consideration of the street as a unit of analysis. A definition of block-face should include properties of the block boundary and be associated to a road segment.

The previous chapter established block-face as a critical morphological element. Its translation in the GIS platform is not easily defined and can be interpreted differently. For example, it is often represented by the road segment where the block-face is the distance between two intersections. However this definition does not readily distinguish the two block-faces on each side of the road segment. In the GIS platform a block-face should be defined by a block ID and a road segment ID.

The development of a method that interprets the block-face simultaneously in terms of block ID and road segment ID draws inspiration from the way in which buildings, represented by points, are related to streets, represented by lines. Two main methods exist to link data spatially: proximity and buffer. Proximity is often defined in the GIS platform by the closest distance between a point and a line (perpendicular to the street segment). Several software packages use the proximity command to link parcels represented by address point to the closest axial lines (Stahle, Marcus et al. 2003). Similar method is used by the software Confeego (Gil, Stutz et al. 2006) and to link centrality measures to data associated with parcels and building (Sevtsuk and Mekonnen 2011).

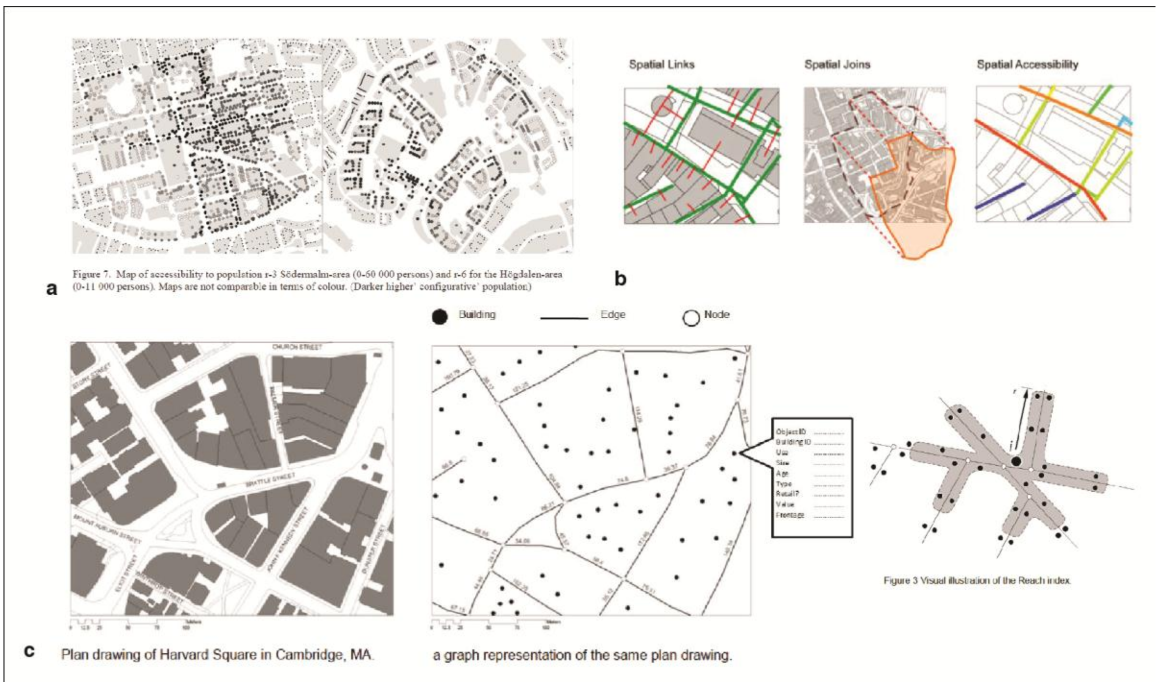


Figure 20. Software using proximity as the shortest distance between a point and a segment: a) Place Syntax software linking address point to axial map (source: Stahle, Marcus et al. 2003); b) Confeego (source: Gil, Stutz et al. 2006) and c) Urban Network Analysis toolbox for ArcGIS (source: Sevtsuk and Mekonnen 2011)

Buffer method requires that the boundary of a polygon is offset to define a "catchment area". The method is used to link buildings to adjacent buildings (Colaninno, Cladera et al. 2011) and simplify data representation in cartography (Boffet and Serra 2001; Gaffuri and Trévisan 2004; Steiniger, Lange et al. 2008). The buffer method be will later explored and used for calculation of building frontage, as well as for linking block-face to road segment. These methods are appropriate when parcels follow the boundary of blocks, which is often not the case in our sample. Instead, “the radial-buffer method” is created. This method is more time consuming but has advantages that will be seen later.

3.3.1 Spatial relationships by identifiers: containment and proximity

The first step is to link our four layers spatially. Each layer is made of either lines or polygons with unique identifiers [ID]. Centroids are extracted from the polygon. Centroids are calculated within the GIS platform ArcMap and are “forced” inside the polygon. They share the same identifier as the polygons. In case of lines, the two endpoints are extracted and they retain the identifier of the road segment. Identifiers allow tracking relationships from one layer to another. The final map is composed of: 1) a road centerline layer made of polylines with unique identification number [ID] that are defined by 2 end-points [sgt_ID]; 2) a block layer based on the street centerline and comprising polygons with unique ID [Sgtbk_ID]; 3) a second block map from the consolidation of parcels composed of polygons with unique ID [Bk_ID], and finally 4) a building footprint map made of polygon with unique ID [Ft_ID].

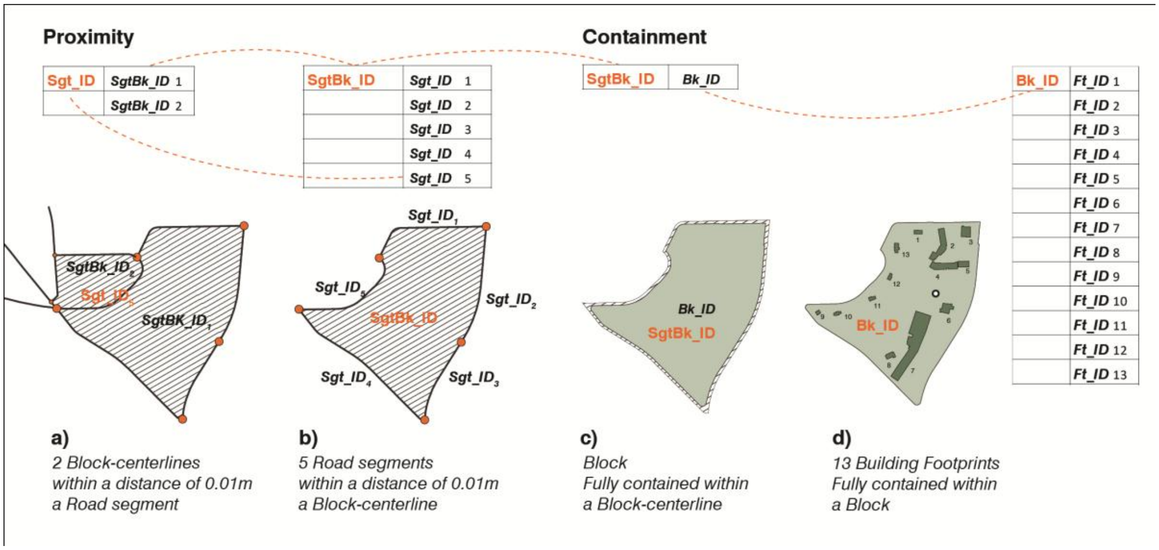


Figure 21. Spatial relationships of proximity or containment between road segments [Sgt], block [Bk] and building footprints [Ft] in the GIS platform.

The four layers have spatial relationships or joins which are either containment or proximity within a threshold distance. Road segments are associated with one or more blocks-centerlines by spatial proximity (Figure 21-a). Several road segments define the boundary of the block-centerline (Figure 21-b), which fully contains one or several block-parcels (Figure 21-c). A block-parcel in turn fully contains none or several building footprints (Figure 21-d). Blocks are elements that share direct spatial relationships to both road segments and building footprints. Lines of road segments are making the outline of the block polygon and the block polygon that contains the building footprint polygons. The following chapter will focus on the difference between blocks as defined by street centerlines and blocks defined by aggregation of adjacent parcels. Once spatial relationships are established within our four layers, the next step is to assign identifiers of street and block to differentiate block-faces.

3.3.2 The radial –buffer method

To define a single block-face in the GIS platform, three elements are needed: a road segment ID, a block ID and the side of the road segment, either left or right. The buffer-method combined with the radial-method assign these three characteristics to a block-face. The radial-method requires several steps (see appendix D “Radial-routine” for a more comprehensive step by step description). The radial method links 13,603 road segments to 4,028 blocks, and will be used in a later chapter to link block-face to building footprints. 72 radials link the centroid of a block to its perimeter every 5 degrees (Figure 22-ab). Blocks may have more than 72 radials due to internal streets or convex shapes; it is the case for 825 blocks.

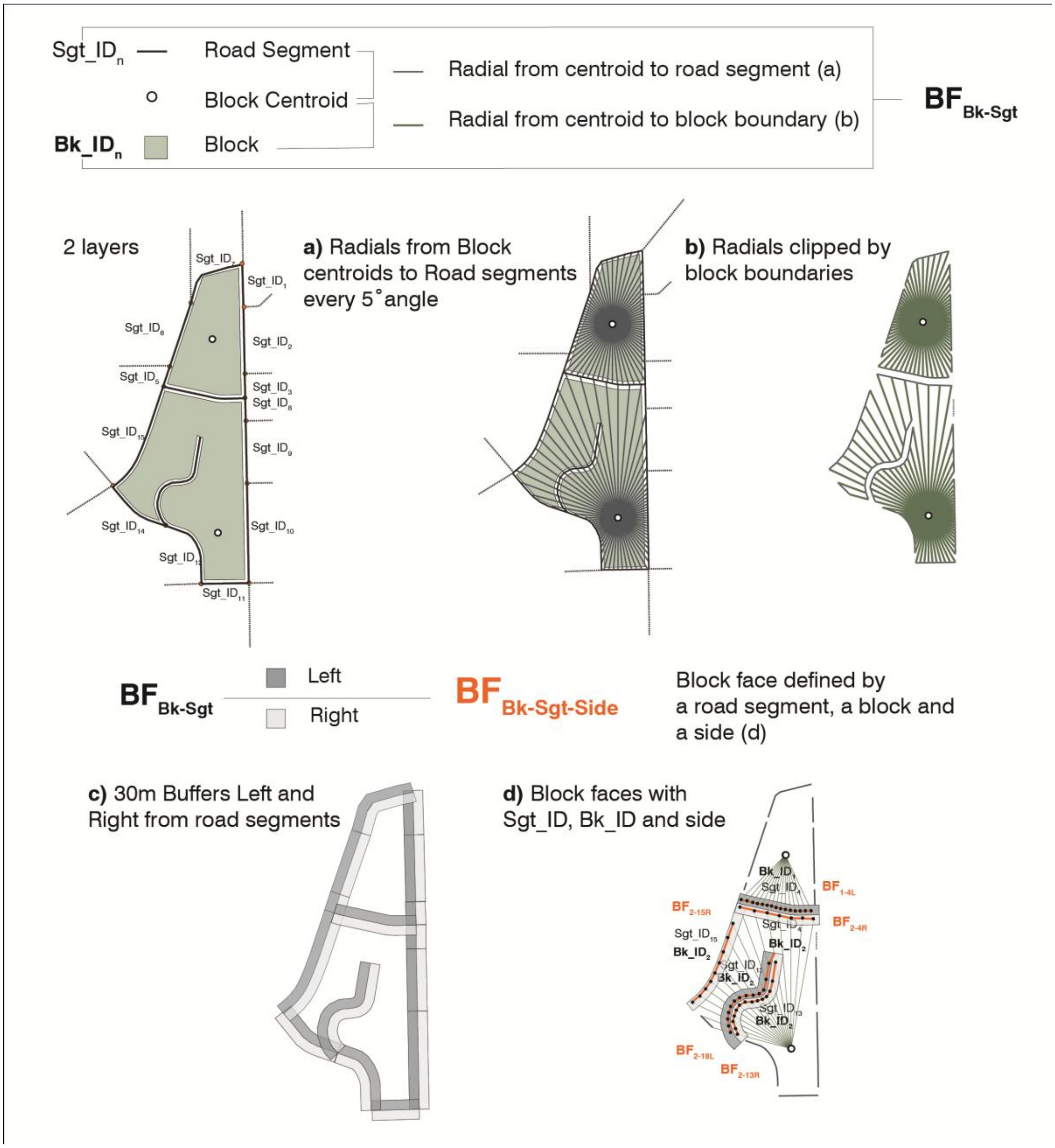


Figure 22. Radial and buffer methods applied to two blocks: a fairly regular concave block and a convex block with internal street. Starting from the existing map with unique ID for road segments and blocks: a) radials from centroids to perimeter every 5 degrees; b) radials clipped by block-faces; c) 30m buffer on each side of road segments to distinguish block-faces with same block and road segment ID; d) block-faces with 2 identifiers and a side.

The radial method of linking road segments to block and later to building footprints has some inaccuracies and limitations. First approximately 500 street segments are not intersected by any radial mostly if the block is too large or the road segment is too short, which represent 3.9 percent of the sample. Second, the two block-faces of internal streets cannot be distinguished since they share same segment and block identifiers, 395 road segments (2.6 %) are concerned. To fix the two faces problem, each road segment is offset by a constant distance (for example 30 meters) on the left and then the right side. The two created buffers help in distinguishing points of the radials belonging to each side (Figure 22-c). Finally a block-face is defined by the points that are linked to a block, road segment and the left or right side of that segment (Figure 22-d). Other methods such as creating points every given distance, 10 meters for example, on each road segment and linking them to the centroid (or perpendicular) might include the smaller segments (Carpenter 2012) but there again some limitations arise.

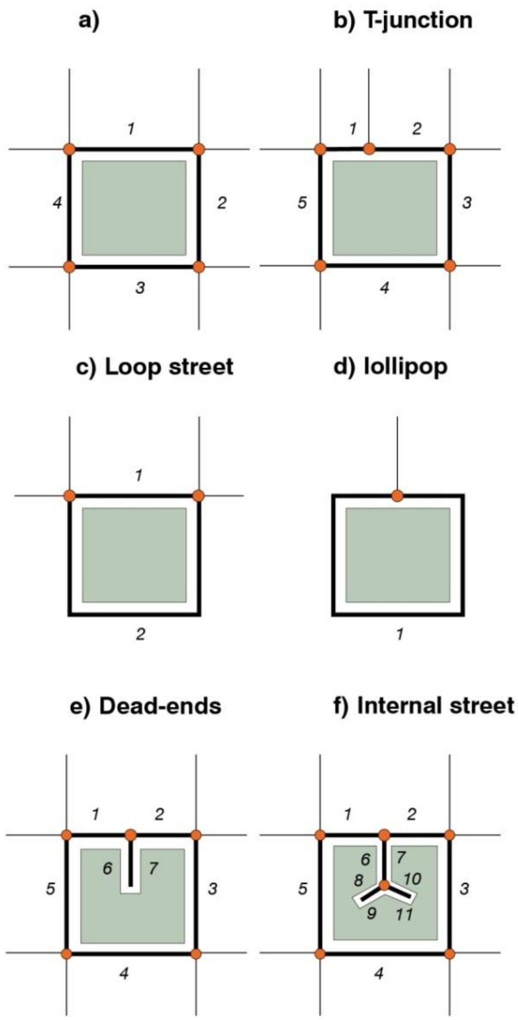
Table 4. Block-face as a morphological unit associated to 3 other elements: block-parcels, radials and road segment. The table gives their type of representation in GIS, their unit measure, their number and the type of points associated to their representation.

Morphological Units	Abv.	Type	units	n	Type points
Block-parcels	[Bk_ID]	. Polygon . Polyline	Square meters Meters	4 028	. Centroid
Radials	[Rad_ID]	. Line	Meters	314 394	. 2 End-points . 1 mid-point
Active Road segment	[Sgt_ID]	. Polygon . Polyline	Square meters Meters	13 603	. Centroid
BLOCK-FACE	**[BF]**	**. Points** **. Polyline**	**NA**	**29 570**	**. n End-points**

23,104 block-faces are extracted from 13,603 road segments (3.5% missing) and 4,028 blocks. The distinction between the faces of a block can help create a hierarchy of use for these faces: most likely, block size and shape naturally differentiate "back alley" from main frontage. For example rectangular shapes tend to geometrically distinguish 2 long sides and 2 short sides (New York), whereas a square equalizes its 4 sizes (Barcelona). It seems that 4 faces should be the average number of faces. However in this study according to our definition of block-face the result is different mostly because of street not going through a block splinting the road segment into two, creating T-junctions.

3.3.3 Number of block-faces

[def.] The number of faces per block corresponds to the number of road segments associated to a block with adjustment in case of internal road segment. Internal road segments include road segments that are associated with the same block on both sides: cul-de-sacs and road segments linking them to the periphery. Therefore, the internal road segments counts for two block-faces. Figure 23 illustrates the different translations from road segments to block-faces.



	a	b	c	d	e	f
# Road Segments	4	5	2	1	6	8
# Block-Faces	4	5	2	1	7	11

Block · Intersections — Road segments

Figure 23. Number of block-faces based on road segment. The distinction between (b) and (e) is the source of the pressure on the boundary: external (b) or internal (e). The variation between number of road segments and number of faces happens when there are internal road segments: dead-ends (e) or internal street (f). Blocks (c) and (d) are cases of block partially or fully contained within another block.

The number of block-faces represents the potential pressure for fragmentation from the surroundings and the actual pressure from the inside by incisions (Vialard 2012). As shown in Figure 23, the increase in the number of faces is due to T-junctions (Figure 23-b). From the T-junctions, cul-de-sacs which apply a pressure on the block periphery coming from the interior (Figure 23-e) are very different from the T-junctions n of the exterior. Block with only one face are blocks that are completely surrounded by another block (Figure 23-d), and blocks with two faces are block partially surrounded (Figure 23-c). In both cases, their accessibility is limited since it is dependent on another block. The increase of external T-junction is linked to connectivity, but the local connectivity increase by cul-de-sac does not correlate to increase of global connectivity.

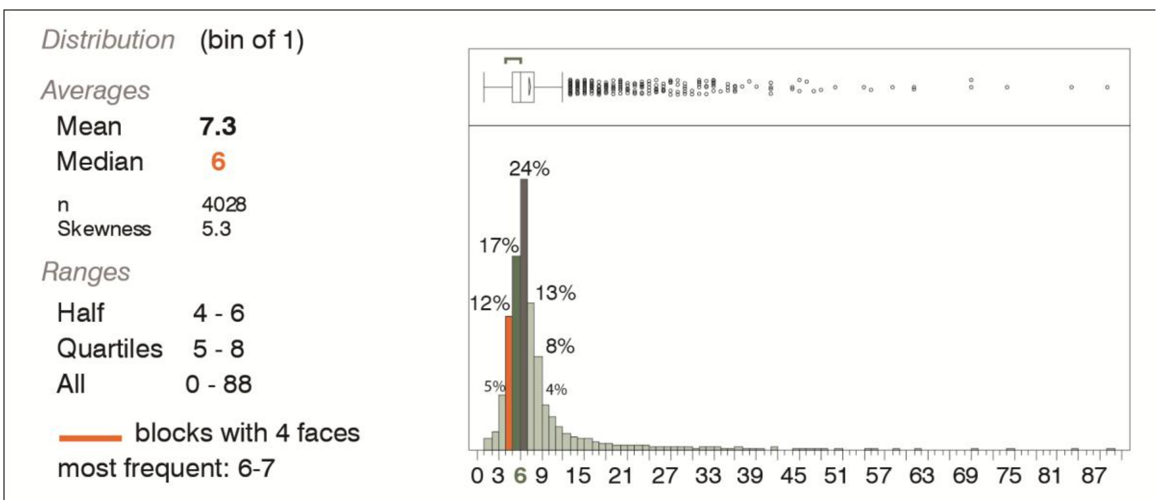


Figure 24. Distribution of number of faces per block with averages and ranges values.

In Figure 24, the distribution shows that blocks have an average 7.3 faces, with a median value of 6. Half of the sample around the mean ranges from 5 to 8 faces and when compactly measured has from 4 to 6 faces. The most recurrent type is block with 6 faces representing 24 percent of the sample, followed by blocks with 5 faces (17 percent), blocks with 7 faces (13 percent) and, block with 4 faces (12 percent). Blocks with only one face, which are blocks fully surrounded by another block, represent one percent of the sample with 34 cases, and 63 blocks are partially surrounded (2 percent).

3.4 Discussion

This later presentation of block-face underlines an inconsistency between how we, designers, might conceive a block and the actual existing conditions. A traditional block is generally conceived as a convex shape with four different sides approximating either a rectangle or a square. In some cases, the design can be more curvilinear to create more organic shapes. This theoretical view of the block as the norm is now questioned. A block with 88 faces seems hard to conceive or to design, but it exists. Concave blocks and internal streets are the sign of irregularities which might not be designed as such but reveal the limitations of the na□ve conception of blocks as relatively compact simple convex polygons.

Atlanta as a case-study emphasizes a type of urban form that might not be the most efficient, or at least not the most obvious to design: dead-ends, lollipops and the irregularity of its street layout work together to create such form. However, such diversity and irregularities are the physical attributes of urban sprawl, which is an urban form that can be found in all North American cities. The challenge is then to unpack the mechanism embedded in the street layout that produces such complex forms. By disaggregating data by block-face, the diverse conditions of streets are highlighted depending on their relation with blocks and building footprints. Highways, dead-ends and internal streets do not produce the same block-faces as traditional streets. The buildings located inside a block, lining a dead-end, or placed along a highway will adapt to the conditions of the street they are facing. Highways, dead-ends and internal streets do not participate the same way on local and global connectivity as regular streets; they have their own purpose, that will affect in turn the type of buildings in the adjacent blocks.

The idea of a block of ideal dimensions does not fit with the existing city. The design of city requires understanding the potential changes and alterations that can occur if a block morphology is not suited to the forces of development or connectivity prevailing at a point in time. The morphology of a block is dependent to the existing state of the city, but it is also very dependent on the external pressure of the street and the internal pressure of the building. And the block-face is the element that carries the response of urban form to both pressures.

CHAPTER 4

CITY PROFILE: SIZE AND SHAPE

This chapter focuses on the measurement of the size and shape of building footprints, streets and blocks in the city of Atlanta. Block size and shape are the principal constituents of city form and the manner in which different shapes and sizes coalesce in the context of a given area is key to the ability of a city to act as a differentiated whole.

A simple quantitative profile of the city is established first, including the statistical distribution of the dimensions of buildings, blocks and streets and the proportions of the city that are covered by the most significant intervals of larger or smaller elements. The second part focuses on the quantification of block shape. Geometrical shapes can be measured in several ways and the selected measures describe two aspects of a block: the periphery, which is in contact with the street, and its internal metric depth, which provides a framework for the location and size of building footprints. The aim is to describe the fit or lack of fit between footprints and blocks. The third part built of the chapter builds upon these simple dimensions of block to describe the shape in terms of complexity by comparing different indexes of shape compactness. Their correlation with block sizes lead to select two shape indexes that capture the complexity of the boundary and the elongation of the overall shape.

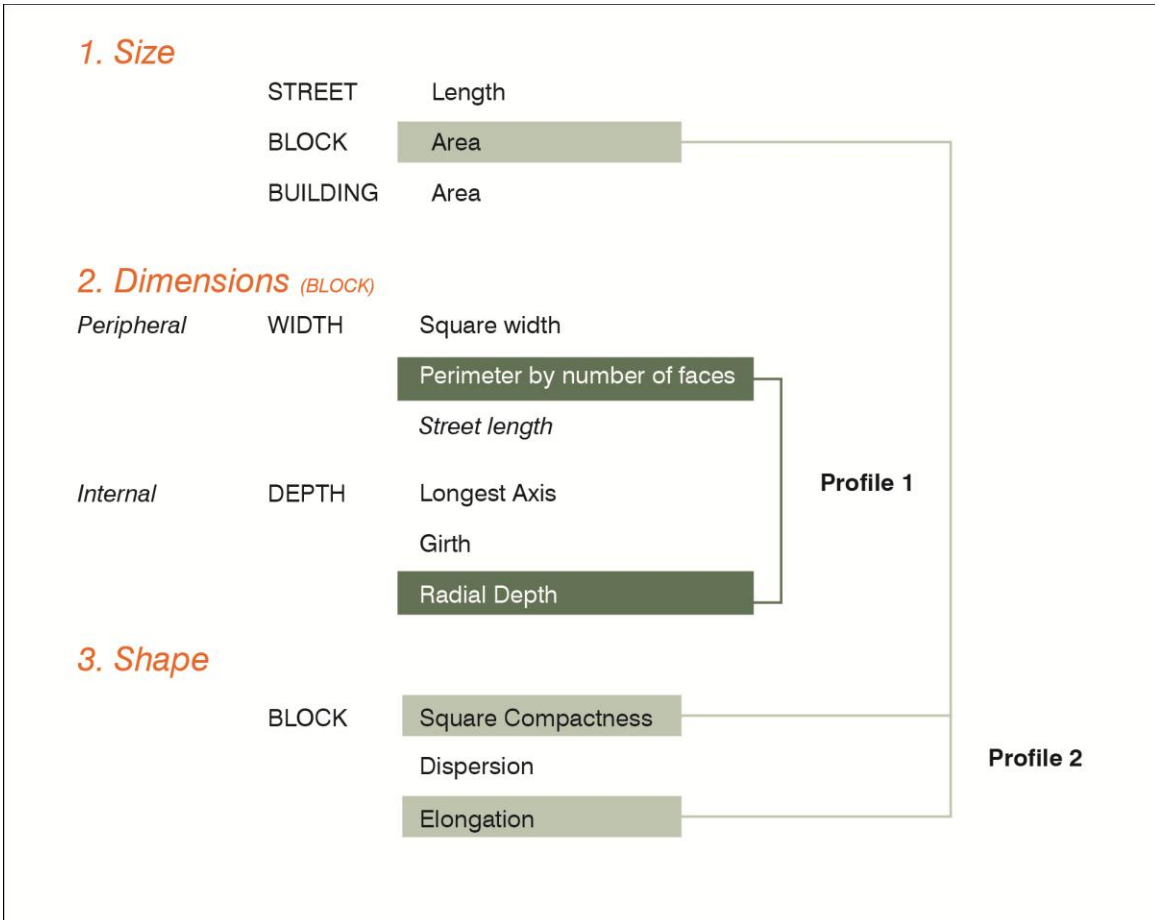


Figure 25. List of all the measures presented and discussed in this chapter and their participation to the establishment of 2 profiles for the city of Atlanta.

4.1 Size: distributions and coverage

This section establishes a profile of the city of Atlanta in terms of building area, block area and street length. However, single values such as the mean or the median are limited when it comes to representing a large diverse sample. Therefore a set of ranges is included to better describe the main trends. These values are also compared with other cities where possible. Distributions highlight the frequency of occurrence of a size interval. Size intervals are also meaningful from the point of view of the amount of space occupied by each, its coverage. Building coverage and street coverage are specified as a percentage of the overall land. The pair of values describes the built-up area, which represent the amount of a block occupied by building footprints, and the street area, the amount of block occupied by the streets. In conclusion, Atlanta is compared to neighborhoods in other cities which have more traditional urban form. This exercise places Atlanta as a city with a very diverse and extreme block sizes, with a fairly low building coverage as well as a fairly low street coverage.

4.1.1 Size: distributions

The first set of figures to be examined focus on distributions and give two types of information: averages and ranges (Figure 26). For averages, the mean value is given for the size of streets, blocks and buildings. To control the significance of the mean value, the median value is also given although it is not an averaged value. Two representations of key ranges of values are given. First, the limits of the upper and lower quartiles around the median highlight the location of half the sample values in the distribution. The narrowest interval of values that can encompass half the same is given – this is not necessarily the same as the inter-quartile range indicated above. In the description of the city, the most frequent values indicate the main trend from which elements depart or not. Finally the minimum and maximum values are indicated for reference.

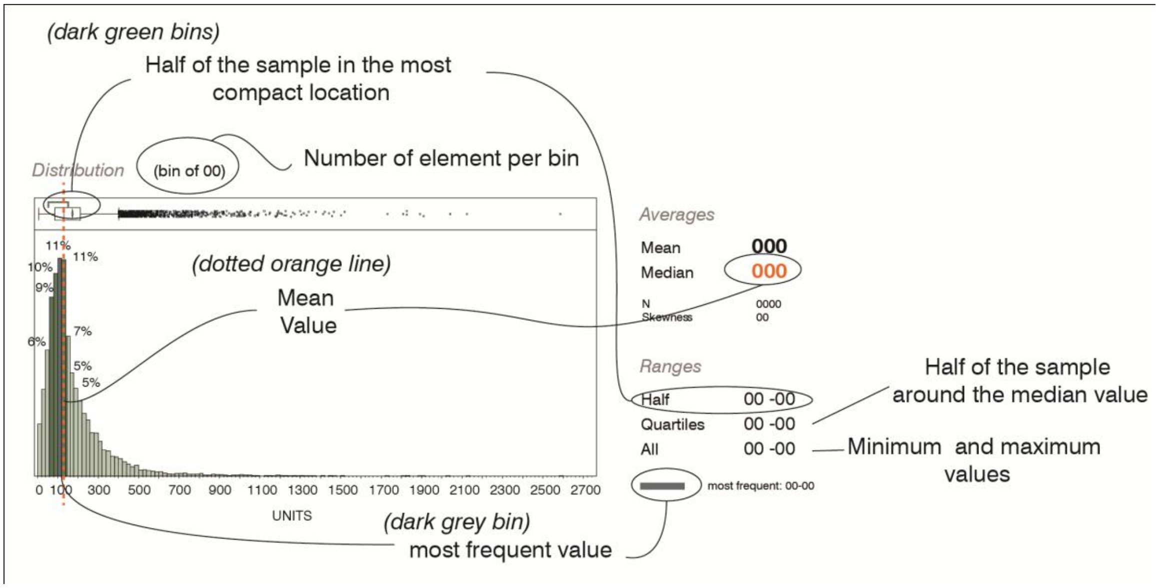


Figure 26. Typical representation of distribution graph with the “average value given by the mean and for comparison the median value. The second set is for 3 sets of ranges.

Streets

[def.] Previously defined in chapter 3, the street network is represented as sets of street segments spanning between two intersections, each street segment made up of a string of one or more centerlines. The size of road segments is given by the length in meters. Besides the distribution of road segment lengths, the average and range values are provided for the length of streets that share the same name.

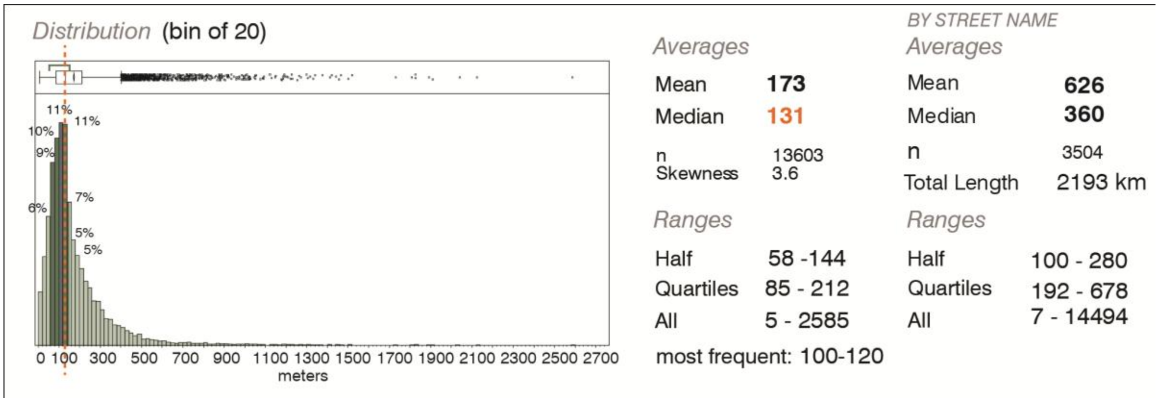


Figure 27. Distribution of road segment length in meters with 20 meters bins (averages and ranges) and distribution for road with the same name.

For Fulton County within city limits, around 13,600 street segments run over 2,350 kilometers (1,460 miles). The average length of a street segment between two intersections is 173 meters (568’). The average length of named streets is 626 meters (2,050’) which is 3.6 times longer. As stated previously, the final focus of this dissertation is the block-face. However, looking at named streets as units of analysis gives a perspective on the potential participation of the street segment to the global network. Considering street segments, the median value is 131 meters (430’), which is significantly lower than the average length. Of course, this lies in the interval that captures 50 percent of the sample, from 58 to 144 meters (190-472’). This interval can be considered as representative of the main trend. The skewness of the distribution shows a very homogeneous sample around the mean and median with very few extremely long street segments. These extremely long street segments usually correspond to interstates (half of the street segments above 1 kilometer). However, the longest street segment of 2.6 kilometers (1.6 mile) corresponds to “Sandy Creek Road” which is a dead end street located near the Fulton airport. The length of such dead-end streets implies very large blocks to accommodate them.

Blocks

[def.] As described earlier, blocks are initially defined by contiguous parcels bounded by streets. The aggregation of parcels disregards the space of the street. It is based on property limits. The area is given in hectares.

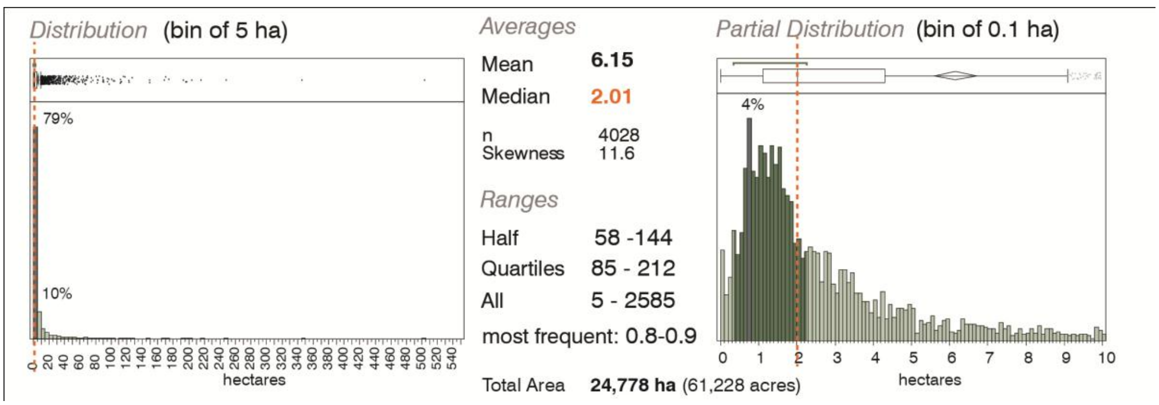


Figure 28. Distribution of <u>block area</u> in hectares with 5 hectares bins and zoomed in partial distribution for the blocks under 10 hectares with 0.1 hectare bins (averages and ranges).

In this sample, 4,028 blocks cover about 25,000 hectares (61,776 acres). The average size of a block is 6.15 hectares (15 acres) while the median value drops to 2 hectares (5 acres). The extreme skewness of the distribution with a long tail for the large values shows the same trend as the distribution of road segment length, which is expected. Ninety percent of the blocks are less than 10 hectares (25 acres). In the zoomed distribution of the blocks under 10 hectares (Figure 28-on the right), more variations are visible. The compact half of the blocks is located under the mean value and comprised between 0.33 (0.81 acres) and 2.26 hectares (5.6 acres). The most recurrent size, which is between 0.8 and 0.9 hectares (around 2 acres), is not well represented by the mean. The largest of the block is 80 times bigger than the average size, 250 times bigger than the median value.

Building footprints

[def.] Because of inaccuracies in the drawing of the GIS map, buildings are represented by aggregated footprints. This means that adjacent buildings are consolidated within as single footprint. The area is given in square meters. It should be noted that building footprints smaller than 12 square meters (130 sq. ft.) have been removed.

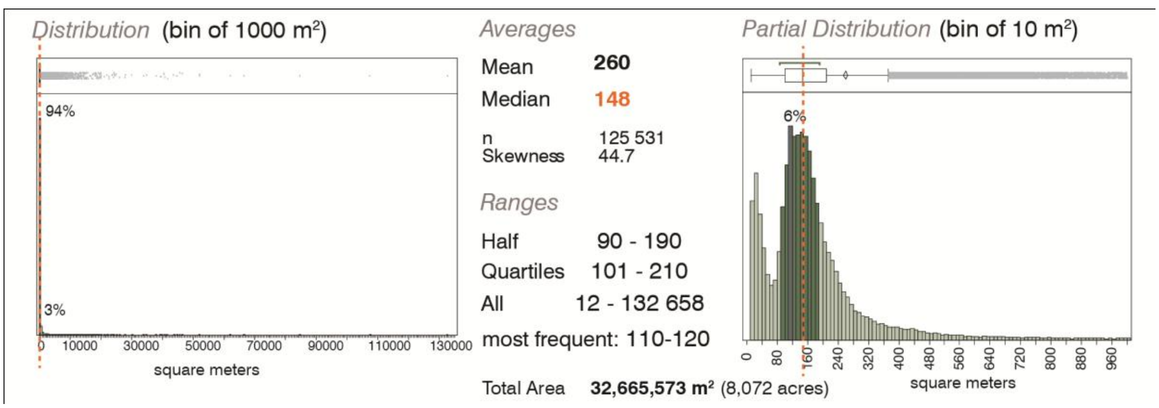


Figure 29. Distribution of aggregated building footprints area in square meters with 1000 square meters bins and zoomed in distribution for the footprints under one hectare with 10 square meters bins.

For the city of Atlanta that lies in Fulton County, 125,531 aggregated building footprints cover around 3,266 hectares (8,071 acres). Their distribution in Figure 29 behaves in a similar way as blocks. In average, buildings footprints measure 260 square meters (2,800 sq. ft.) while the mean value equals 148 square meters (1,600 sq. ft.). Half of the sample based on quartile values is located between 101 and 210 square meters

(1,090-2,260 sq. ft.) which is more or less the same as the narrowest range that includes half the sample. These values again are lower than the average size of building footprints showing the limitations of the mean value when the distribution is highly skewed. The most frequent footprint size is between 110-120 square meters (1,185-1,290 sq. ft.). The largest aggregation is over one million square feet and corresponds to the Lenox Square shopping center.

Summary and comparison

Table 5. Summary distribution for Street, Block and Footprints (averages and ranges)

		units	*n*	*MEAN*	*MEDIAN*	*HALF*	*QUARTILE*
Road Segments	*length*	*meters*	*13603*	173	131	58-144	85-212
Block	*area*	*hectares*	*4028*	**6.15**	**2.01**	**0.33-2.26**	**1.1-4.3**
Building Footprints	*area*	*m^2*	*125531*	260	148	90-190	101-210

The distributions for street lengths, block areas and building footprint areas are behaving similarly. They all have very skewed data showing the asymmetry of the distribution with very few very large or very long elements. The main concentration of values is around the median value, far from the mean. One of the conclusions is the need to use mean values with caution. They are not always representative of the overall city. In Atlanta's case, the distribution shows a very homogeneous distribution around the median values for both blocks and footprints. The skewness of the distribution shows that as elements increase in size they are less frequent. Atlanta offers a very large range of different block sizes and has produced very different sizes of building footprints. For example, footprints are 230 times smaller than the average and 134 times smaller if the median block size.

The following Table 6 presents how many blocks in Atlanta fall into the block size categorization presented in the review of literature (see paragraph 2.2.4). The reader will remember that in comparing downtowns grids of North American and Australian cities, Siksna (1997) characterized as small blocks those with an area below 10,000 square meters (2.5 acres), as medium blocks those between 10,000 and 20,000 square meters (5 acres), and as large blocks those above 20,000 square meters.

Table 6. Comparison of Atlanta block sizes with other cities (from review of literature)

Categories of Block Sizes	*City grids*	*Area*		*Occurrence in Atlanta*
		hectares	*acres*	*% of Total*
SMALL (Siksna)		*<1*	*<2.5*	**21 %**
	Lisbon/Baixa (Marat)	0.17-0.25	0.4-0.6	
	Historical Savannah	0.25	0.6	
	New Urbanism	0.8	2	
	Edinburgh / New Town (Marat)	0.84	2.1	
MEDIUM (Siksna)		*1-2*	*2.5-5*	**29%**
	San Francisco (Moudon)	1.06	2.6	
	Barcelona/Ensanche (Marat)	1.24	3.06	
	Downtown Atlanta	1.46	3.61	
LARGE (Siksna)		*>2*	*>5*	**50%**
	Edinburgh / New Town (Marat)	2.5	6.2	
	Center Milton Keynes (Walker)	4.8	12	
SUPERBLOCK *		*50-100*	*125-250*	**2%**
	Radburn (600by300)	18	45	
	Brasilia	49	121	
	Islamabad	64	158	
	Milton Keynes	100	250	

**Superblock often refers to the peripheral road that defines a block not the block made of parcels.*

According to this categorization, half of the Atlanta sample belongs to the large category. Small and medium size blocks are present in significant numbers also. The range of blocks sizes might be a characteristic of Atlanta's diversity of urban forms. However, other cities show similar ranges. Although springing from a study of regular downtown grids in large cities, the categorization in small, large, medium and superblock changes the definition on what is thought to be the norm for block size. It raises the question on the importance of large blocks that might not be numerous but cover an important amount of land. Questions arise as to whether very large blocks can be dismissed as exceptions, under what conditions can they be treated as early stages of a process of block fragmentation and what block sizes may be required in order to accommodate the larger footprints that seem possible.

4.1.2 Size: coverage

As defined in the previous chapter, footprints of blocks and buildings are enclosed areas with distinctive boundaries. For streets, the area boundary is difficult to establish directly. The surface taken by streets is therefore taken to be equal to the area of land that is not occupied by parcels. This area will be called street coverage. In other studies, building coverage is referred as building density or site coverage – the ratio of building footprint area by the area of the site (Cheng 2010). The relationship between the built and the non-built space has been also called the "Ground Space Index" (Berghauser Pont and Haupt 2002). Building coverage, block coverage and street coverage are the amount of space or area taken by each element and are given as a percentage of the total amount of land. The total amount of land encompasses Fulton County within the city limits of Atlanta which has an area of approximately 28,800 hectares (71,150 acres).

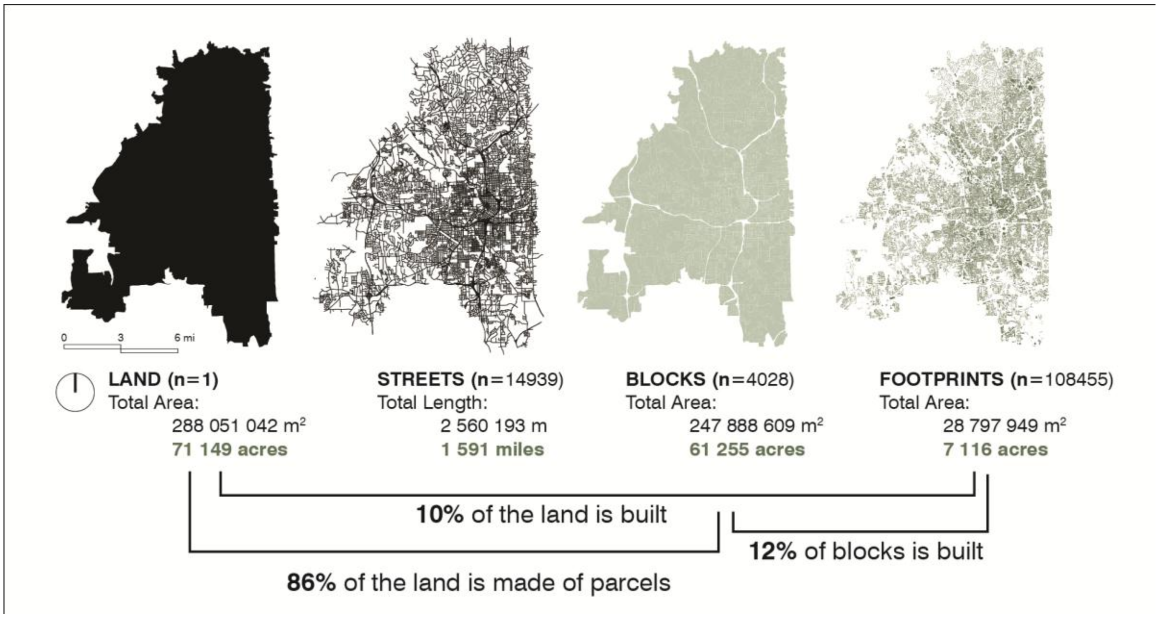


Figure 30. Atlanta's overall figures and relationships for Land, Street, Blocks and Building footprints.

In Figure 30, the blocks cover 24,800 hectares (61,555 acres), which represent around 86 percent of the available land. According to this gross figure the leftover area for the streets represents approximately 14 percent. On the other hand, building footprints cover only 2,879 hectares (7,110 acres) which is only 10 percent of the overall land or 12 percent of the land covered by the urban blocks. In the city of Atlanta, roads are occupying more land than actual buildings.

To simplify the comparison with other cities, building coverage is paired with street coverage (percentages). For Atlanta it is respectively 10-14 percent. A study of neighborhoods of Baixa in Lisbon, of New Town in Edinburgh, and the Ensanche in Barcelona, by Marat-Mendes (2002) measures the built-up area and the area of the street layout in these three traditional and recognizable urban forms. The pair "building-street percentages" is respectively 52-39 (= 91 percent of land), 45-43 (= 87 percent of land) and 32-35 (= 67 percent of land) of the total area. By comparison, the pair 10-14 (=24 percent of land) of Atlanta shows that buildings in Atlanta are very sparse and the streets area is 2.5 times smaller than the lowest pair of the Ensanche.

The average block size in each city (Table 6) shows that in general the smaller the blocks - as in Baixa and historical Savannah - the higher the percentage of land that is taken by buildings and streets. Urban fabrics with small blocks tend to produce a higher ratio of both building and street coverage.

4.1.3 Frequency and coverage of blocks

Another way of looking at the significance of block sizes is to include not only the occurrence/frequency of a certain size but also its coverage, how much of the land it occupies. In the following section, frequency and coverage are calculated separately and then plotted cumulatively (Figure 31). The repartition of ranges of block sizes into bins is based on Natural Breaks as calculated by the algorithm of ArcView GIS 3.3 for 10 intervals[11].

The distribution of coverage shows a comparable significance of all intervals as for land coverage. Very few large blocks cover the same amount of land of a thousand small blocks. Blocks ranging from 0 to 22 hectares (55 acres) cover half of the territory as shown on the Cumulative Coverage histogram. More than half of the blocks are smaller than 2.8 hectares (7 acres) but only represent 12.5 percent in terms of coverage (natural

[11] In ArcView GIS, natural breaks are computed according to the Jenks optimization method that uses the goodness of variance fit (GVF) to minimize squared deviation of the class means (ESRI website Support (Article ID: 26442): What is the Jenks optimization method?) Jenks, George F. 1967. "The Data Model Concept in Statistical Mapping", International Yearbook of Cartography 7: 186-190.
The reason for selecting Natural breaks algorithm over Quantiles and Equals Intervals classification is that it combines both aspects and as such equalizes both frequency and coverage.

break 1). If natural breaks 1 and 2 are merged, 83 percent of the blocks cover one third of the total area. The middle third is covered by classes 3 to 5 and the last third by classes 6 to10. The 40 largest blocks cover a quarter of the entire land of this sample which can also be covered by 3,300 smallest blocks. There are very few very large blocks but the area that they occupy remains significant.

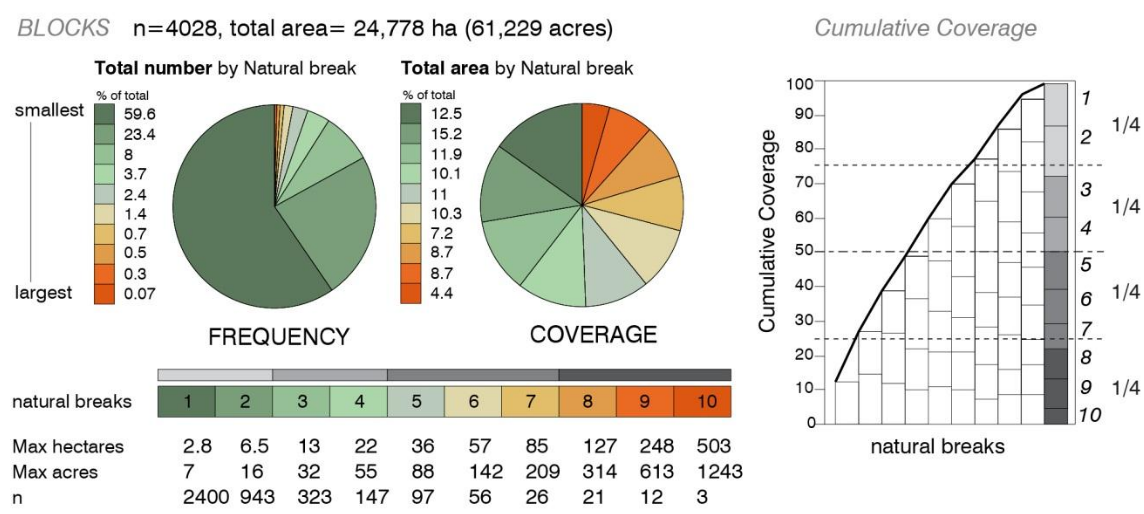


Figure 31. Frequency and Coverage of block area for 10 natural breaks. The cumulative coverage pairs natural breaks together into 4 larger classes (grey).

Occurrence of a block type hides its significance in regard to the amount of land it occupies. A very large block can cover a very large amount of land or the same area can be made of several small blocks. The difference is that to bypass the large block is much harder than to go in between smaller blocks. Size of the Area gives a measure of how much land is available to build, but the way we build is based on characteristics that go beyond availability of land. One essential characteristic is accessibility. Access can be done two ways: by placing the building along the boundary of the block or next to an internal road.

When it comes to urban design there are generic considerations characteristics that are embedded into any design. In this regard, a parallel can be made with the design of buildings. Steadman (2000) proposes a classification of building types (archetypes) by defining characteristics that are dependent on external factors such as the availability of natural light and the placement of interior corridor to expand the number of rooms with both physical access and natural light. The third characteristic is the courtyard that increases the amount of natural light from the interior of a building. Urban design functions in a similar way. Buildings are located on the periphery to fulfill both the need for natural light and accessibility. To increase the number of buildings, internal roads, like corridors, are built. The equivalent of a courtyard is the open space at the center of the block. The comparison between buildings and urban settings has some limitations, such as the change of scale. But the main principle remains: design is dependent on generic and functional constraints. Finally the important element that produces variations of the archetype is the notion of dimensions and in particular of “depth”. Buildings are usually dependent on access to light therefore a maximum depth is usually recommended. Such dependence creates particular configurations and determines, to some extent, the location of buildings in the block. To capture the relationship of building configurations and blocks, the measurement of area is not enough, the shape of the block is as important.

4.2 Dimensions of Block Shapes

Area best describes the amount of land covered by blocks, but size of blocks can also be depicted with linear dimensions. Regular block shapes such as square and rectangular blocks are often represented by length and width. For irregular shapes, such dimensions are harder to define. From the multiplicity of available measures, a distinction exists between measures characterizing interior distances (depth) and dimensions characterizing the perimeter of the block (perimeter length and comparison to reference shapes such as the square). In the introduction of this chapter, the city is presented in terms of accessibility. This section brings into the discussion the two types of block dimensions answering the questions: what distances does it take to bypass a block? What distance does it take to access its center? The first measure informs about the accessibility of the block from its surroundings, or how much of the block is in contact with the street. The second set is important for the placement of buildings in a block and regards the flexibility of the shape to accommodate buildings as well as the accessibility to the center of the block.

Dimensions from center to perimeter are referred as “depths”; they describe internal properties of blocks. Dimensions describing the overall proportions of block at the periphery are referred as “widths”. The first set of measures computed characterizes block width. Block area and perimeter are used to calculate them. The second set of measures characterizes block depth with: the longest axis, the shortest axis, the shortest distance from centroid to perimeter and the average distance from centroid to perimeter.[12]

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[12] To measure internal dimensions, except the radial depth, we use the Shape Metrics Tool developed by Jason Parent and available online [http://clear.uconn.edu/tools/Shape_Metrics/index.htm]. It calculates the

Finally the dimensions that represent Atlanta's block stock are compared to dimensions from recognizable and regular cities.

4.2.1 Width: peripheral dimensions of blocks

In regular shape the side of a block is easily described by the width and the length. For irregular shape the meandering perimeter does not allow to extract these dimensions. Alternative measures are proposed: the first method compares the area of block to a square of the same area and the second divides the perimeter and number of block-faces. In both cases the resulting dimensions are abstract dimensions. The last dimension that has affinities with the idea of block width is the length of road segments.

Square Width

[def.] The 'square' width of a shape is the square root of its area, which is equivalent to the width of a square of equal area.

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longest axis, the girth and other measures that will be needed to compute index of compactness. The tool is a Python script that runs out of ArcToolbox in ArcGIS 9.3. It requires a polygon as an input. The measures are explained in detailed in a published article: Angel, S., J. Parent, et al. (2009). "Ten compactness properties of circles: Measuring shape in geography." Canadian Geographer/Le G□ographe canadien **54**(4): 441-461.

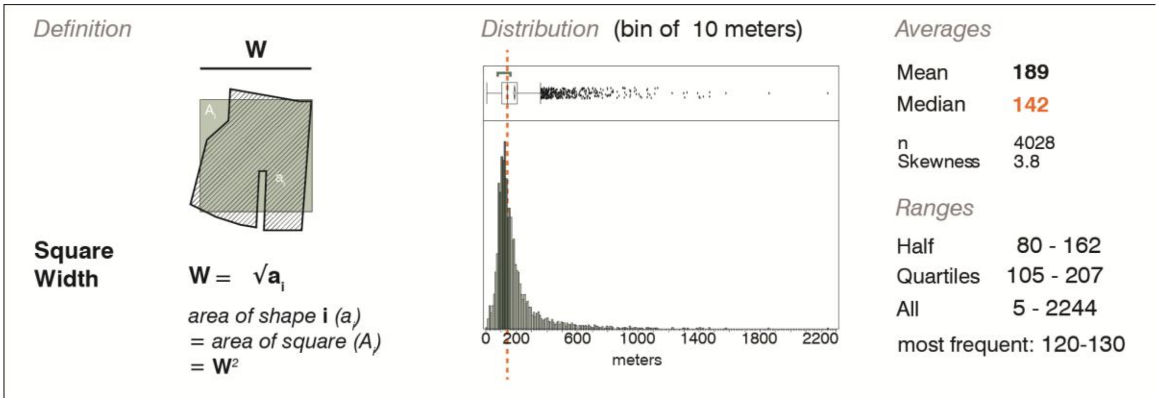

Figure 32. Definition and distribution of <u>block square width</u> in meters (averages and ranges).

Square widths of blocks in our sample have a mean value of 189 meters (620') and a median value of 142 meters (466'). The most frequent lengths are comprised between 120-130 meters (394-427') which is lower that the averaged values. Half of the lengths range from 80 meters to 162 meters (260-530'), which shows variations up to double length. This estimation of dimension for a theoretically equivalent block-face is a little far from the reality if one bears in mind the preceding chapter that shows that blocks with four block-faces are not the norm.

<u>Average Length</u>

[def.] Another way to measure the block face is to use the perimeter, sometimes also used to measure block size (Song and Knaap 2007). The perimeter is used for the calculation of average length of the sides of a block. Average side length is the division of the perimeter of a block by the number of block-faces associated to that block. The number of block-faces is defined in the previous chapter. The median number of faces is 6.

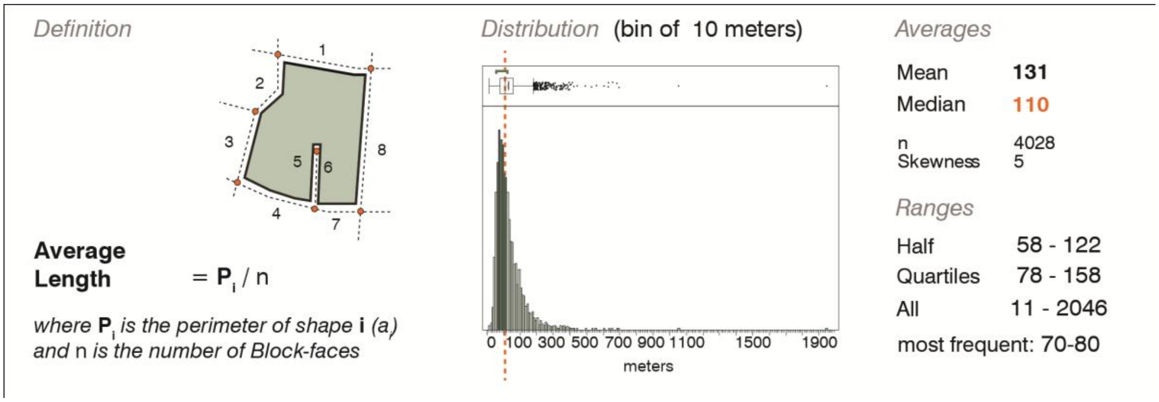

Figure 33. Definition and distribution of the block average length in meters based on perimeter and number of block-faces (averages and ranges).

The lengths of block-faces have a mean value of 131 meters (430') and a median of 110 meters (360'). The most recurrent dimensions are around 70-80 meters (230-260') and half of the blocks are located between 58 and 122 meters (190-400'). The distribution follows the same trend as previously with a long tail for the high values. However the values are slightly lower than the ones given by the square root. This is not surprising given the fragmentation of the perimeter into more than 4 sides.

4.2.2 Depth: Internal dimensions of Blocks

The other dimensions that complement the peripheral distances are the internal dimensions of shapes. The longest axis and girth are descriptive measures of internal features of shapes: the overall span and the maximum internal span. They are descriptors of internal distances from perimeter to perimeter. The relationship of girth and longest axis helps to determine what type of building configurations can be accommodated by a block. It is an indicator of block potential.

The second set of internal dimensions describes the relationship from the center of a shape to its perimeter in terms of “depth” and radial depth. These dimensions are useful to determine the location of buildings on the block in terms of setbacks for example.

Longest Axis[13]

[def.] The longest axis of a shape is the straight line connecting the two furthest-apart points of its perimeter. It is equivalent to the diameter of the smallest circle that fully contains a shape. A shape can have more than one longest axis, for example a square has two longest axes and they are passing through the centroid, a circle has an infinite number.

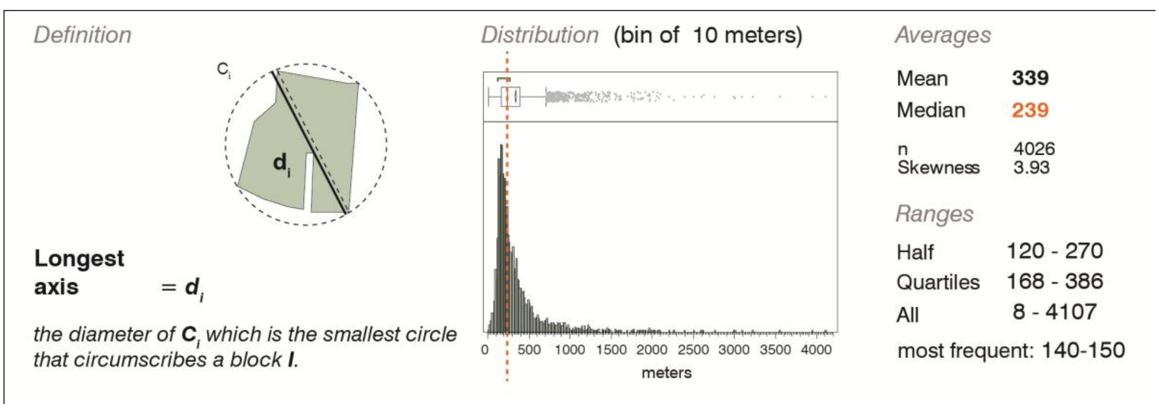

Figure 34. Definition and distribution of the block longest axis in meters (averages and ranges).

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[13] The Longest axis is calculated by a script developed by Parent, in which it is called range. The longest axis is also used to calculate the compactness of shape in terms of Elongation.

The mean value is 339 meters (1,112') and the median value 239 meters (784'), a hundred meters less. The distribution shows a concentration of values between 120 and 270 meters (393-886') for block. The most frequent values range from 140 to 160 meters (460-525'). The longest span is 4.1 kilometers long (2.6 miles).

When calculated for building footprints,[14] the longest axis indicates the minimum distance that is necessary for a building to be accommodated into a shape, i.e. a block (see appendix E "Fit test" for potential application)

Girth

[def.] Girth is the radius of the largest circle inscribed in a shape. Girth is sensitive to the innermost point(s) of the perimeter shape.

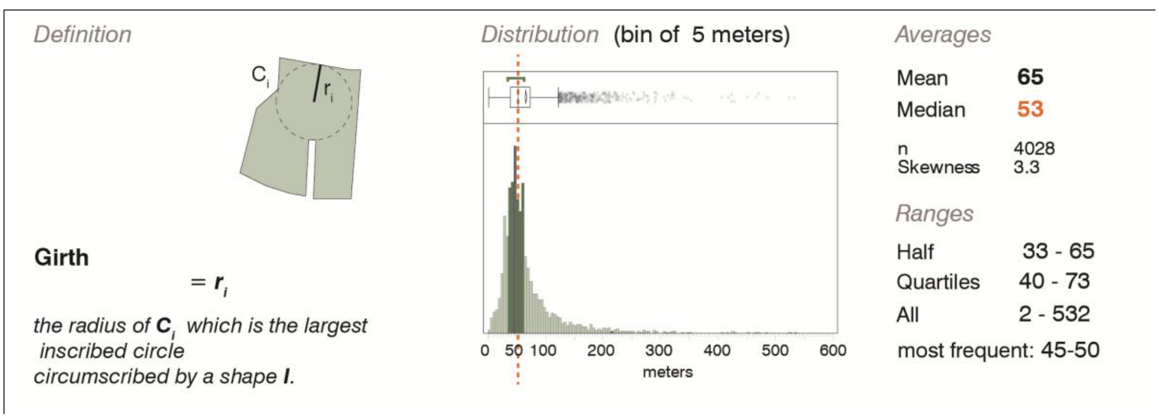

Figure 35. Definition and distribution of the block girth in meters (averages and ranges).

The block stock shows an average girth of 65 meters (213') and a mean of 53 meters (174'). The block girth when double gives the maximum span that can be

[14] For the building stock, the mean value for the longest axis is 21.8 meters (72'), the median is 18.7 meters (61') and the values range from 0 to 725 meters (2,378').

occupied by a building footprint. When it is calculated for the building footprints, the interest is to determine the relationship of the periphery with natural lighting. It gives the innermost point of a plan, the deepest point from the fa□ade. Girth for a building has a mean of 5 meters (16’), a median of 4.7 meters (15’), maximum value of 117 meters (383’) and half of the buildings are located between 4 to 5.5 meters (13-18’). The value of girth for the building is very close to the value[15] presented in a survey of Cambridge, UK (Brown and Steadman 1986; Steadman, Evans et al. 2009) where the total depth for houses approximate 7-8 meters (23-26’). In a study of four English towns and survey of non-domestic Building stock, the depth of buildings, measured by offset every 1m, split into two categories: the largest around the value of 14 meters and the second set has depth ranging from 18 to 22 meters (Steadman, Bruhns et al. 2000). For Baixa in Lisbon the building depths average 10.5 meters, 15 meters in New town in Edinburgh and 20-28 meters for the Ensanche in Barcelona.

Radial Depth

[def.] In irregular shapes, the shortest path from centroid to the perimeter of a shape is not always representative of actual ‘depth’. The option for the calculation of depth

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[15] “*Now the fact is that most habitable rooms in modern dwellings have dimensions in plan of around 3 or 4 m. (Obviously there are many exceptions.) This we may assume has something to do with the typical space requirements of domestic activities and their associated furniture and equipment. In dwellings that are two rooms deep this would imply a total plan depth of around 7 or 8 m. Brown and Steadman (1991) made a survey of a random sample of 300, mostly 19th- and 20th-century houses and flats, in Cambridge, UK. They measured their depths in plan in every case (ignoring minor back extensions) and obtained a mean value for the whole sample of 7.4 m. Breaking down the sample by house types, they found mean depths of 7.2 m for terrace houses, 7.7 m for semi-detached houses, and 7.4 m for flats. These they showed were the consequences of placing pairs of habitable rooms with dimensions of 3–4 m, back to back. Detached houses were somewhat shallower, with a mean of 7.0 m, because some were, at least in part, just one room deep.”* Steadman, P., S. Evans, et al. (2009). "Wall area, volume and plan depth in the building stock." Building Research & Information **37**(5): 455-467.

selected here is related to the Compactness measure developed by Boyce and Clark in 1964 for irregular shapes. They use radials departing from the centroid of the shapes. In their description of the measure, the number of radials is limited to 16. MacEachren reaches a consensus of 40-50 radials (MacEachren 1985). This present calculation uses 72 radials to capture another aspect, the built form, the equivalent of having radials at 5□ angle intervals. The method was presented in more detail in the previous chapter. Radial depth is defined the average length of all the block radials.

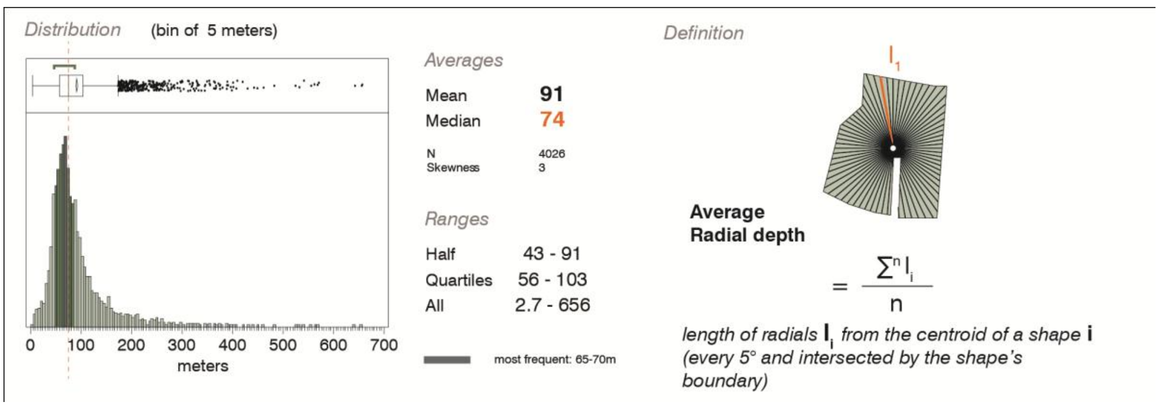

Figure 36. Definition and distribution of the block average radial depth in meters (averages and ranges).

The mean value is 91 meters (299'), the median is 74 meters (243'), and the most recurrent values are comprised between 65-70 meters (213-230'). These lengths are telling how far someone would have to walk in average from the center of a block to the street. The depth radials will also help to measure the setbacks of building in the blocks, as the front line of building footprints will intersect the radials.

4.2.3 Profile 1: width and depth

<u>Summary of block dimensions</u>

Block widths are summarized in Table 7. The table includes square width, average length of sides, the average length of road segments, and the double radial depth. Block depths are also specified as twice the girth, half of the longest axis and as an averaged radial depth. The diversity of linear measures presented below suggests a possibility to understand city blocks dimensions more specifically and also tighten the range of values that are the most recurrent.

The graph in Figure 37 shows the location of half of the sample and the mean value for all the precedent measures.

Table 7. Block dimensions and occurrence.

WIDTH	*units*	*MEAN*	*MEDIAN*	*HALF*	*Frequent*
Square Width*	*meters*	189	142	80-162	120-130
Average Length*	*meters*	**131**	**110**	**58-122**	**70-80**
Radial Depth x2*	*meters*	182	148	84-182	130-140
Segment Length	*meters*	173	131	58-144	100-120
DEPTH					
Longest Axis/2	*meters*	170	120	60-135	70-80
Girth	*meters*	65	53	33-65	45-50
Radial Depth*	*meters*	**91**	**74**	**43-91**	**65-70**

*****averaged dimensions

The most recurrent block faces are comprised within a range of 80 to 210 meters (262’ to 688’) which coincides with the distances found in the literature. For the downtown of Atlanta, the length of a block-face is 128 meters (420’), and for historical Savannah it measures 91 meters (300’) and 55 meters (180’). In an effort to measure sprawl, Ewing, Pendall et al. (2002) predicate that traditional urban blocks should have a side of around 152 meters (500’). For a sustainable urbanism, Farr (2007) recommends to position streets at intervals no greater than 180 meters (600’). This places Atlanta as a city with regular dimensions compared to other North American cities, but with a high proportion of blocks on the larger side.

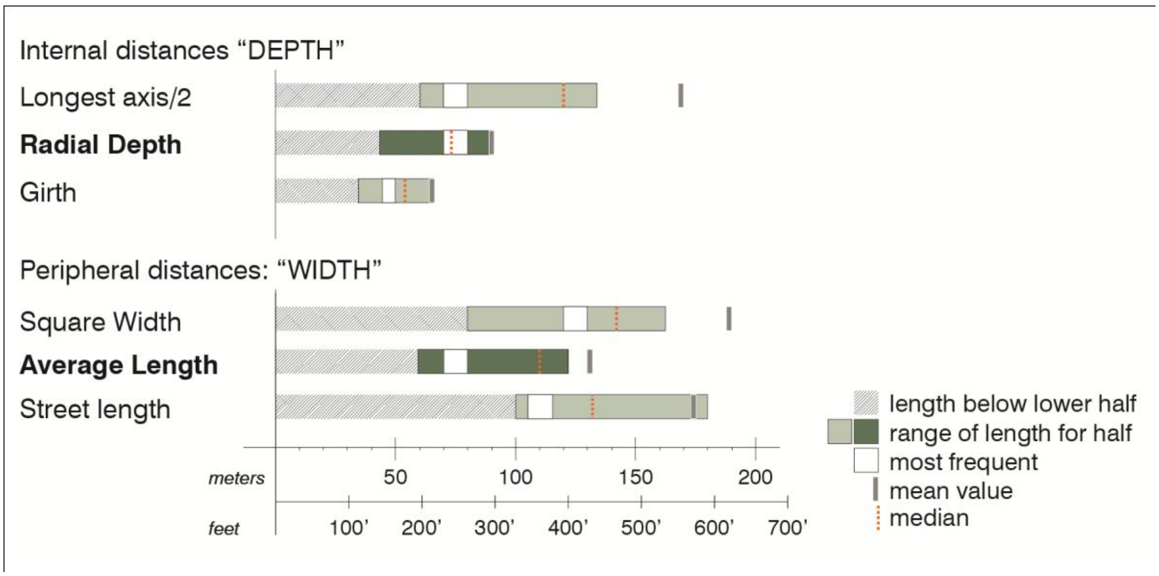

Figure 37. Linear dimensions of Blocks: depth and width

The peripheral dimensions of block faces are indicators of amount of potential frontage while the depth measures indicate the potential to accommodate footprints, setbacks and inner open spaces and backyard.

<u>Atlanta’s profile 1</u>

A first profile of Atlanta that shows the most recurrent type of block dimensions is established based on the selected dimensions for width and depth. To make up the profile, blocks with a radial depth comprised within 43 to 93 meters and with an average face length comprised within 58 and 122 meters are selected. Only 1071 blocks match the two requirements and are illustrated in Figure 38. While the ranges selected were describing half of the sample when considered one at a time, the final selection based on both measures encompasses only a quarter of the blocks. These belong to the small-medium category with an average size of 1.3 hectares.

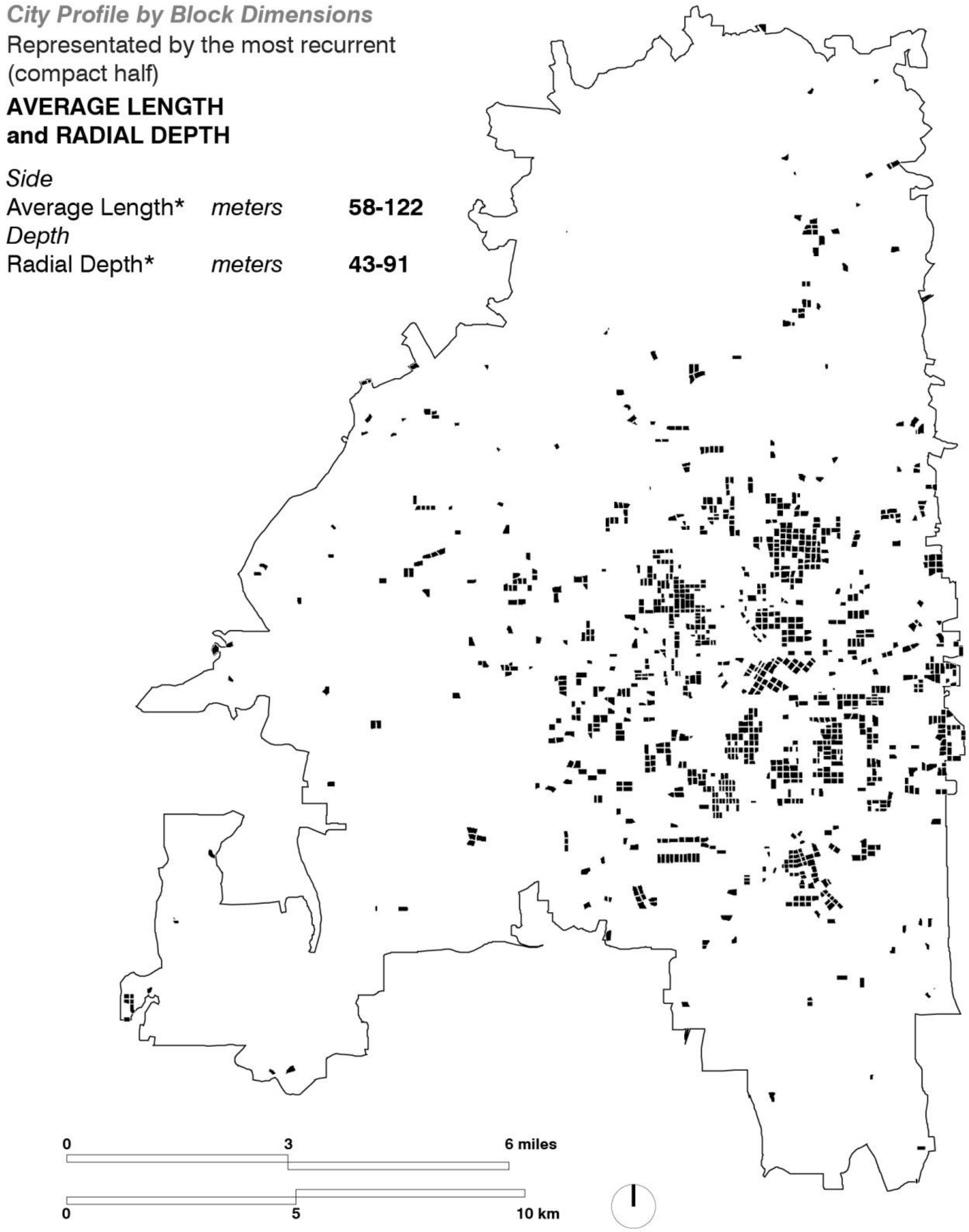

Figure 38. Blocks representative of Atlanta based on their radial depth and average length dimensions. They represent the compact half range (n= 1071).

4.3 Shapes: index of compactness

The most typical measures of shape deal with compactness. Geographers have developed a series of indexes to measure compactness of shapes (MacEachren 1985) which become more complicated to compute if wholes are allowed in the shape.

"Compactness measures do not distinguish between regions with holes and do not indicate edge roughness. Boundary measures are well suited for measuring edge roughness, but little can be done for identifying holes in regions and they are often complex to calculate. The component measures represent a descriptive measure rather than a quantitative (thus comparable) measure for shape." (Wentz 1997) p.210

Two very useful measures for describing floorplate shape have been developed by Ermal Shpuza and John Peponis (2008) in parts drawing inspiration from Bill Hillier's (1996) theory of partitions. The first measure, intended as an efficient measure of compactness, is called Relative Grid Distance (RGD). Given a tessellated representation of a shape, RGD measures the distance from each tile to all others and then relativizes the average by comparison to a square of the same area. The second measure, Convex Fragmentation (CF), is intended as a measure of how far the shape is "broken" into parts by virtue of irregularities of perimeter or internal holes. CF measures the number of "turns" needed to go from each tile to all others. Recently, Shpuza has applied the measures to describe the shape of cities around the Adriatic, but this work has not yet been published. Relative grid distance and convex fragmentation would be the best measures to capture variation of block shapes. However, the automatic computation of the calculation is yet to be implemented. Thus, the measures used here are chosen amongst those that can be effectively computed. These measures are still trying to capture the irregularities of the boundary and the holes, as well as the link from perimeter to center.

Based on the previous dimensions used to measure the side and depth of blocks, this section focuses upon the deformation of the block boundary and the proportions of the block shape. The aim is to understand if block size impacts block shape, and to which extent. For example, if a block is too large, internal streets will be created to access the center and this will compromise the legibility and the connectivity of the block.

The deformation can be measured by the distortion of the perimeter, or by the variations in depths. Distortion implies a reference to a non-deformed shape. The most neutral and stable shape is the circle which does not have a unique longest axis, nor variations in the length of its radials. Therefore, shapes are usually compared to a circle as the most compact form. However, to compute the distortions of the boundary, the square is a more sensitive figure than the circle because in cities, blocks tend to be more rectangular in general. Three shape indexes are presented and used to describe the block stock in Atlanta: square compactness, dispersion, and elongation. According to Colaninno, Cladera et al. (2011), the shape indexes based on the ratio perimeter-area (square compactness) and based on the longest axis (elongation) are both indicator of "complexity" of a shape. Square compactness describes better the boundary and elongation defines better the proportions.

4.3.1 Shape dimensions for blocks

<u>Square compactness: perimeter and area ratio</u>

[def.] Square Compactness is calculated for a block by the ratio of the area to perimeter and how it differs from a square. It is an adapted version of the isoperimetric inequality of curve (Gravelius 1914). In order to account for the variation of the ratio with the change of size, the perimeter is squared and the area is square rooted (MacEachren 1985). The ratio area-perimeter of the shape is compared to the ratio area-perimeter of a square of equal area. Therefore values of 1 are usually defining square shapes. Values range from a little above 0 to a little above 1.2. Values superior to 1 capture shapes that are square with rounded edges or shape that tend towards a circle. Very irregular shapes combined with dead-end streets have values that range from 0 to 0.44. Values comprised between 0.55-0.75 indicate irregular shape without dead-ends and elongated irregular rectangle with dead-ends (see appendix F “Compactness indexes”). The limitation of the index of square compactness is that it does not differentiate very elongated shapes from shapes with meandering boundaries.

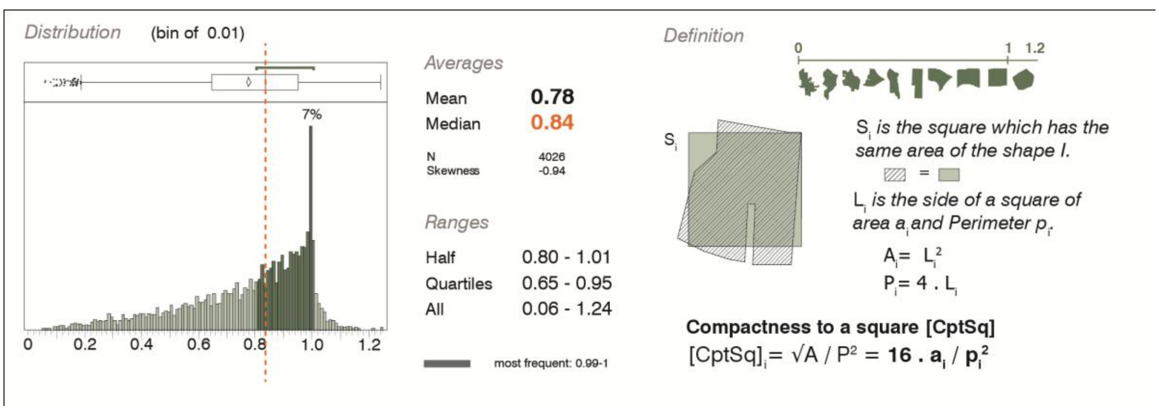

Figure 39. Definition and distribution of the block square compactness (averages and ranges).

Half of the blocks fall within the category of shapes with compactness values ranging from 0.65 and 0.95 (Figure 39). This suggests that cities tend to create fairly regular and compact blocks regardless of their sprawling tendency. The second observation is the asymmetry of the distribution with a negative skewness value that indicates a heavier tail in the direction of small values. As shapes increase in irregularity they are less frequently encountered. Thus, while the city of Atlanta generally encompasses fairly compact and regular blocks, it also has a wide range of very irregular ones. The most recurrent type of block has a value close to 0.9-1, which indicates shapes close to a square.

Dispersion: compactness by radials

[def.] Another compactness measure is calculated by a system of radials traced from the centroid to the perimeter of a shape. Called the Boyce-Clark index, it was developed to measure compactness of geographical shapes such as regions and counties (Boyce and Clark 1964). The radials will be used later to relate street segments to building footprints. A modified version of the Boyce-Clark Index is used in this study that includes the variations of the radial compared to a circle of reference. "Dispersion" describes a shape by the variations of distances between its center and its perimeter, which is equivalent to the variations of its radials. Dispersion is calculated by the average length of the radials of a shape. In the case of a circle, all points of the perimeter are equidistant which produces a constant value of dispersion (Angel, Parent et al. 2009). Thus, the circle is the most compact shape in terms of dispersion. To calculate the "Dispersion Index" for a shape I, the circle with a radius equal to the shape's dispersion value is computed. This circle intersecting the shape creates two equal areas: the surface of the shape I outside the circle (A_{ext}) and the surface inside the circle that does not belong to the shape I (A_{int}). The dispersion index of a shape normalizes dispersion by taking into account the deviations between the perimeter of the shape and the perimeter of the circle, which are the deviations corresponding to the internal and external increments mentioned above.

The formula, as given in Figure 40, requires that the average deviation is subtracted from dispersion and that the remainder is divided by dispersion again.

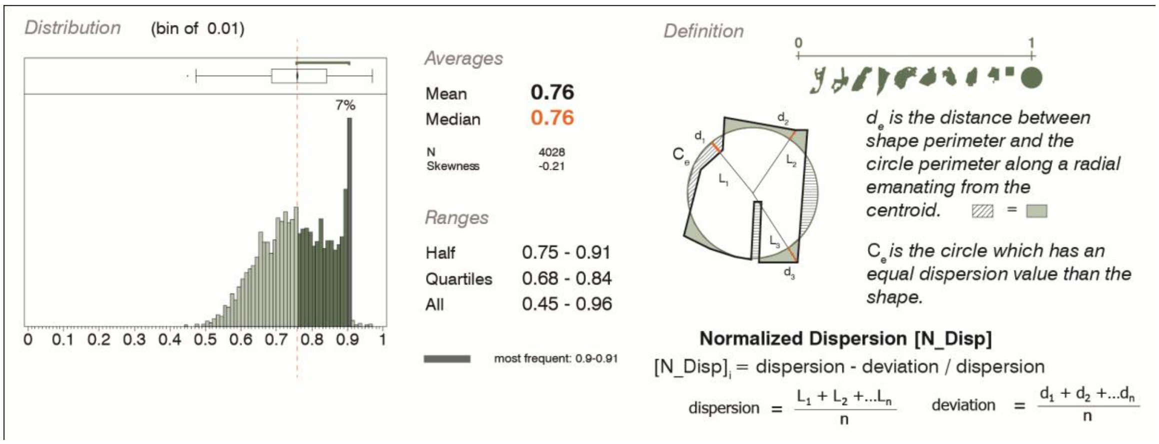

Figure 40. Definition and distribution of the block dispersion (averages and ranges) which is a shape index of compactness based on the block radials.

When the dispersion index is close to 1, the shape propagates itself from the center in all directions; shapes with low values tend to propagate from the center in specific directions. Squares have a dispersion index of 0.9. Very elongated rectangles have a dispersion index of 0.5. A very meandering boundary that loops back and forth from boundary towards the center will drop the dispersion value. While focusing on the distance of the boundary to the center, the dispersion index fails to distinguish very long and narrow blocks from blocks with long and multiple internal streets. The scale of comparison is also limited; it ranges from 1 to 0.45. Dispersion is given as an indicator but will not participate in establishing the city profile by shape and size.

Elongation: compactness by longest axis

[def.] The longest axis gives a sense of size and shape. It is equal to the diameter of the smallest circle that fully circumscribes a shape. Schumm (1956) developed a compactness measure based on the longest axis, called the basin elongation[16]; this is provided in Figure 41. Later on the longest axis will be used as a parameter to compare shape to each other.

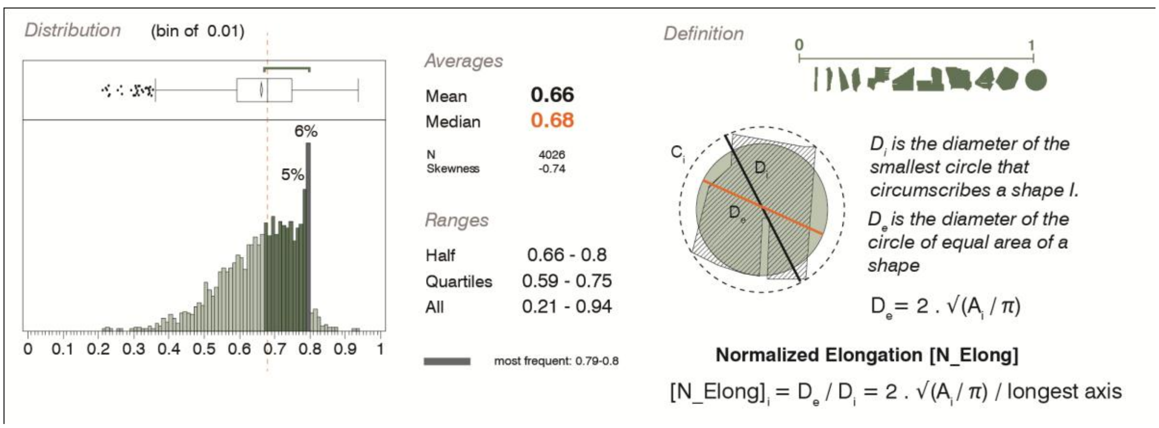

Figure 41. Definition and distribution of the block elongation (averages and ranges) which is a shape index of compactness based on longest axis.

The elongation of shape is captured by the compactness measure including the longest axis in its formula. The elongation index equals 1 for a circle and its values decrease as the shape is elongating. A square has an elongation of 0.79-0.8; a rectangular shape varies depending on its side ratio: the higher the ratio, the lower the

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[16] Shape elongation is also documented by BARD with length to width ratio of the minimum bounding rectangle. Their aim is to simplify maps according to the scale of representation (AGENT study). Elongation has also been measured by the ratio of the length to width of the minimum bounding rectangle of a shape [Steiniger, S., T. Lange, et al. (2008). "An approach for the classification of urban building structures based on discriminant analysis techniques." Transactions in GIS 12(1): 3]. In their study they also use the Schumm's longest axis to area ratio.

elongation value. The lowest values are for strips of land near the highway with ratio approximating 20:1. Square blocks are the most numerous and represent 6 percent of the sample. In average the block ratio approximates 2:1. Half of the sample ranges from square blocks to blocks with a side half the length of the other. The very elongated blocks are few.

4.3.2 Profile 2: shape

<u>Summary of block compactness measures</u>

Table 8. Indexes of shape compactness with averages, ranges and occurrence per block.

COMPACTNESS	*index*	*MEAN*	*MEDIAN*	*HALF*	*Frequent*
Square Compactness	*0-1.3*	**0.78**	**0.84**	**0.8-1.01**	**0.99 - 1**
Dispersion	*0-1*	0.76	0.76	0.75-0.91	0.9 - 0.91
Elongation	*0-1*	**0.66**	**0.68**	**0.66-0.8**	**0.79 - 0.8**

The purpose of the shape indexes is to measure the regularity as well as the homogeneity of urban fabrics. Figure 42 shows the range of values within which half of the sample is located as well as the full range of values for the three indexes. The range of values is consistent across the 3 indexes. Square blocks constitute the upper limit of the most recurrent shapes, and the lower limit is made of blocks that have a proportion of 2:1 with a boundary that is slightly deformed.

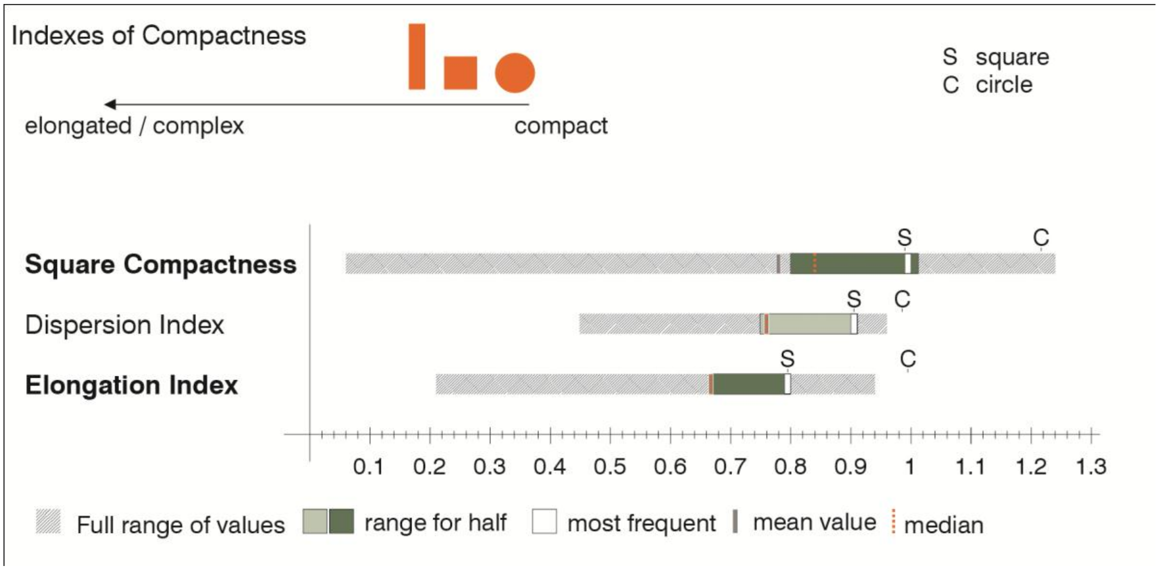

Figure 42. Graphic scale for compactness indexes with averages and ranges.

Atlanta's profile 2

The second profile of Atlanta blocks is based on the block shapes. It is made of blocks with a square compactness lying between 0.8 and 1.01 and an elongation index lying between 0.66 and 0.8. Only 1,173 blocks match the two requirements and are illustrated in Figure 43. Although still small, this profile includes a wider range of block sizes, with an average value of 2.1 varying between 0.01 up to 52 hectares, compared to the profile based on dimensions alone.

The next question is to measure how such profile affects connectivity and the built form. The face and depth of blocks dimensions are used to measure accessibility, at the street level and at the building level. The next chapter focuses on the load upon the block created by street and building footprints.

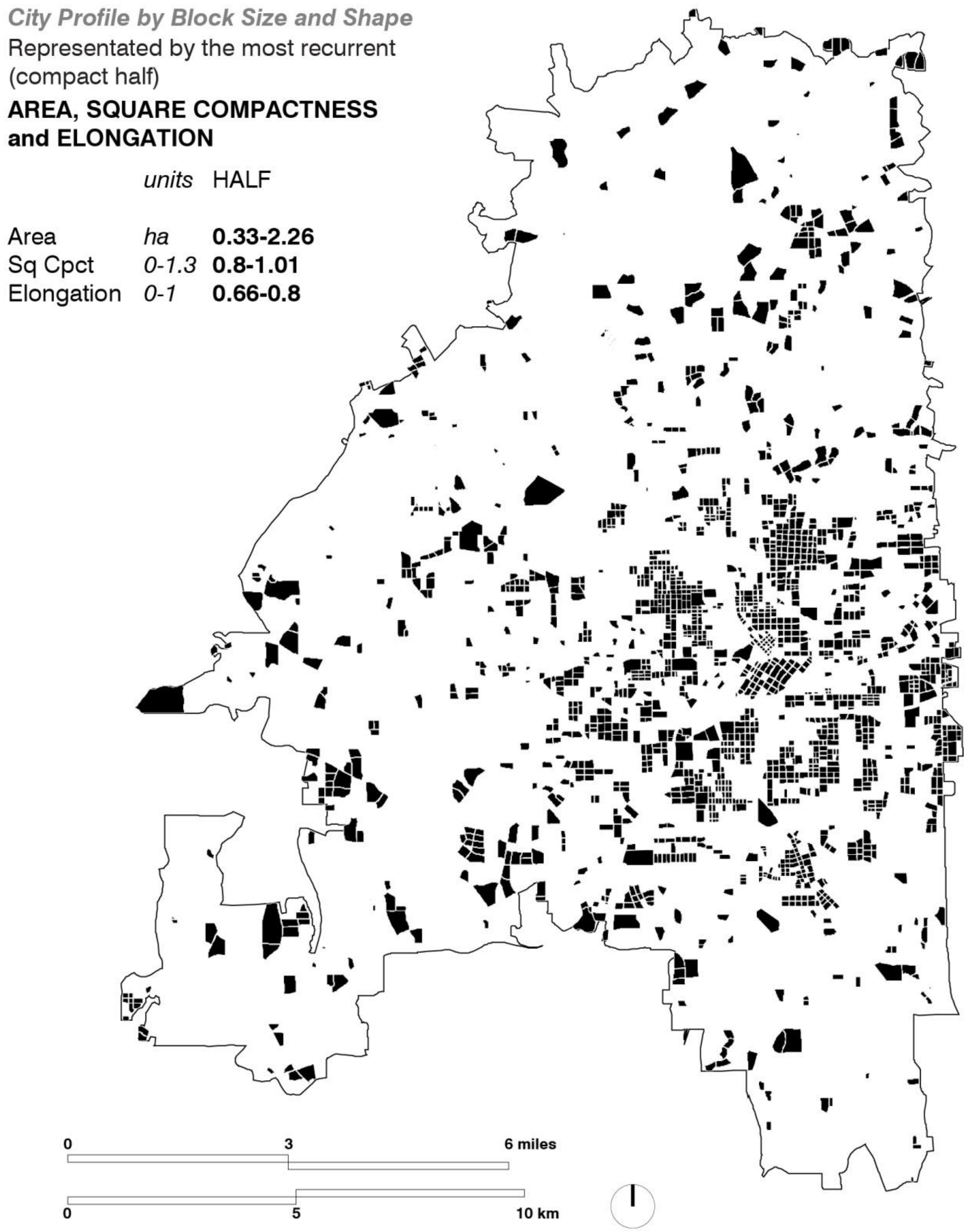

Figure 43. Blocks representative of Atlanta based on their area, square compactness and elongation. They represent the compact half range. (n= 1173)

CHAPTER 5

BLOCK LOADS

A sustainable development is "capable of meeting today's needs without compromising the ability of future generations to meet their needs" (Williams, Burton et al. 2000). Regarding urban form, sustainability is measured by its capacity to adapt to changes over time (Scoffham and Marat-Mendes 2000). Some calls it the "goodness of urban form" (Talen 2005), others call it "the efficiency of urban form" (Colaninno, Roca et al. 2011) arguing for either compact or small cities that behave efficiently.

The balance between street properties and building properties defines the value of blocks (Figure 44). This section presents a set of attributes related first to street layout, and second to building footprints. The measures resulting from the properties of street layout constitute the external load of a block, they represent the forces upon development or block fragmentation that result from the significance of the incident or peripheral streets based on the overall connectivity of the street network. They express the accessibility of the block from a local or global standpoint, as well as the legibility of the urban context, the place of the block in the underlying cognitive maps of the city. The external load is "charging" the block boundary by exercising pressure to increase accessibility by fragmentation and incisions or to decrease accessibility by aggregation. In these circumstances, the purpose of the measures is to assess the ability of streets to remain stable in a particular context to allow a neighborhood to develop and a city to grow at large. But they can also be used later as generators of particular urban qualities that can be reproduced in other contexts.

Previously demonstrated in section 6.3, occurrence of a block type hides its significance in regard to the amount of land it occupies. In the city of Atlanta, the presence of large blocks in the fabric, and not only at the periphery, suggests some repercussion on the global syntactic properties of the street network. A very large block can cover a very large amount of land or the same area can be made of several small blocks. The difference is that to bypass the large block is much harder than to go in between smaller blocks. The other characteristic of very large blocks is the placement of buildings and their accessibility that require internal streets.

Previous work has dealt with this particular point of internal roads emphasizing the difference of syntactic properties with a traditional grid. Albert Pope (1996) described this phenomenon of internal roads configuration as the ladder. The ladder is a system working independently of the peripheral streets. This distinction between internal and peripheral roads is essential to understand the distinction between local and global connectivity. More specifically, the role played by ladder on segregation or isolation of the land it serves. Peripheral roads participate to the global connectivity of the street network. Internal roads participate only loosely to the global structure, over a certain block size, ladders are actually increasing pressure on the global street network, creating only few point of ingress/egress to access it.

Hence the need for syntactic measures that are assigned distinctively to internal street and peripheral streets. The preferred measure is linked to each road segment and not an average values of a given area.

In parallel, the presence and configuration of building footprints represent the internal load of a block. This internal load expresses the density of construction in a given area therefore it implicitly relates to the potential for further development or to the saturation of the urban fabric. The location of buildings in the center or on the edge of the block determines the degree of enclosure or openness of the block. For a passerby, the degree of "enclosure" of the block is characterized by the continuity or the interruption of facades along the streets, in other terms the "built frontage". The report of values for the block, but also for the block-face, is required to link size and shape properties of block or block-faces to behaviors.

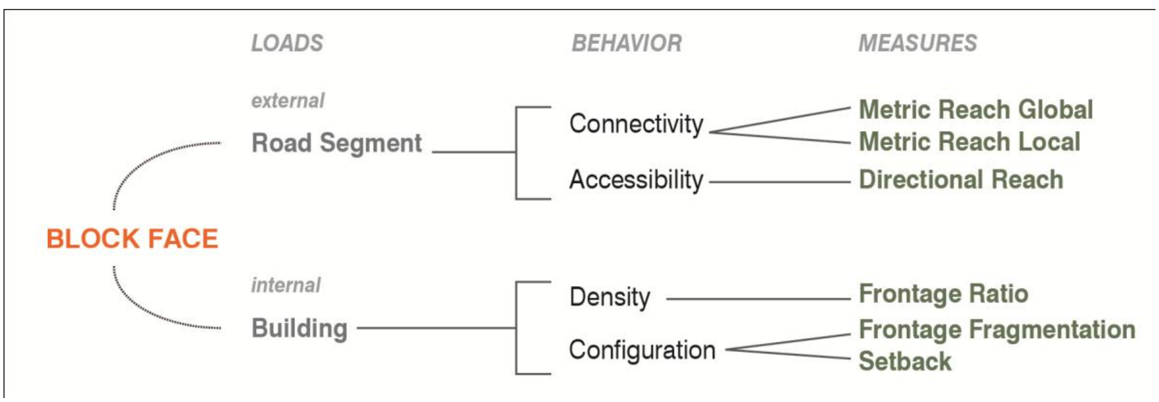

Figure 44. Internal and external loads on the block-face and the measures associated to types of behavior.

The transfer of internal load from block to the block-face is done according to two different techniques so that the potential errors inherent in each are controlled: the offset and the radial methods. Both methods have been primary introduced in chapter 3. The offset technique is based on the street segment and its area of “influence” created by buffers. The radial technique uses the depth of blocks to link the center of a block to its edges, and from there to the closest road centerline. The two methods are further explained in detail below.

5.1 External Load: street configuration impact on the block boundary

The first set of measures focuses on the characteristics of street layout, the street load. Street behavior is principally linked to accessibility and connectivity. Measures of reach reflect these syntactic properties for each road segment: they are first defined and then computed for the city of Atlanta as shown by the histograms.

5.1.1 External street load: measures

The connectivity of a street layout is defined by the amount of street length available within a set reach. At the urban scale, the metric distance and topological distance are incorporated in the measure of metric reach and directional reach (Peponis, Allen et al. 2007; Peponis, Allen et al. 2007; Peponis, Bafna et al. 2008). Parametric thresholds distinguish local from global reach. Each reach measure records a different affordance of the street segment. It is then transferred from the street segment to the two block-faces associated to that road segment. High metric reach and straightness increase walkability as shown in a case study of neighborhoods in Atlanta (..zbil and Peponis 2007; Ozbil, Peponis et al. 2011). They are also linked to the use of public transportation (Ozbil, Peponis et al. 2009). High directional reach is a driver in retail distribution, as shown in a study of Buenos Aires (Scoppa 2013). The metric reach and directional reach of individual road segments are likely to capture variations along a street and metric reach varies with the size of blocks (Peponis, Bafna et al. 2008). The size of blocks in a theoretical perfect square grid shows that the smallest blocks have the highest metric reach value with a strong decrease rate when blocks become larger.

Metric Reach

[def.] Metric reach characterizes street density and street connectivity. It measures the total number of miles that is available for someone departing from the middle of a road segment and "walking" a given distance in every direction (Peponis, Bafna et al. 2008)[17]. The given distance is called radius. Variations in the radius length capture either local street density, with for example radius 0.17 and 0.5 mile, or global street density with radius of 1 mile or more. Metric Reach provides a measure of "potential", how much of the urban fabric is available nearby. It quantifies in length the range of nearby opportunities provided by the street network. To some degree, metric reach captures availability of alternative routes, or street connectivity. A metric reach value is assigned to each road segment to characterize block-face.

The global connectivity is measured by metric reach at radius one and five miles and local connectivity is using a radius of 0.17 mile. The length of 0.17 mile (273 m) corresponds to more or less two block-faces. Radius 0.17 captures the adjacent block sides (local context, local adjacencies) on a "perfect" square grid. In Figure 45-a, starting

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[17] The details of their computation in the ArcView GIS platform is discussed in Peponis, J., D. Allen, et al. (2007). Measuring the Configuration of Street Networks. 6th International Space Syntax Symposium, Istanbul Technical University, Cenkler, Istanbul

from the middle of a road segment, mean metric reach at radius 0.17 mile reaches out to 23 block-faces. Metric reach values at 0.17 mile radius capture if the smaller blocks are within a homogeneous area of other small blocks. High values demonstrate high density and therefore local connectivity.

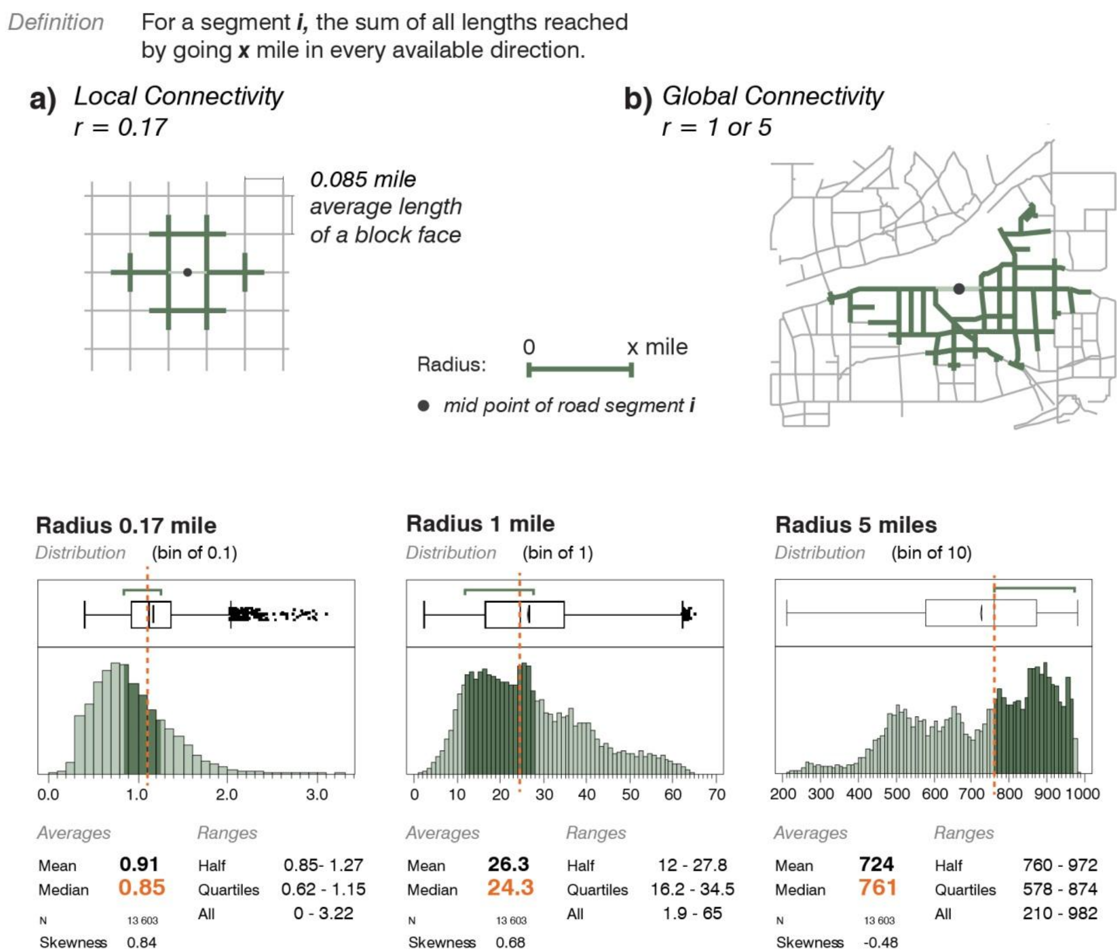

Figure 45. Metric Reach distribution by road segment at radius 0.17 mile to measure local connectivity, at one mile radius and at 5 miles radius for global connectivity (averages and ranges).

For metric reach with one mile radius, the concentration of values is below the mean and median. Half of the sample is located between 13 and 28 miles. Few segments have very high metric reach. Within the sample, the highest reach value is 2.5 times higher than the average value and the lowest 14 times smaller. The skewness of the distribution decreases as radius goes from 0.17 to 1 mile and becomes negative at 5 mile radius. The global structure is highly connected at five mile radius. The lowest connectivity is 40 times the radius and the highest connectivity is 200 times the radius. The shift from a right skewness at 1 mile radius to a left skewness at 5 miles radius indicates a homogenization of the connectivity around the center (less than 400-500 values are located on the edge of the sample). The road segments with the lowest values are located far from “centers” of density (here Marietta and Atlanta).

In a study of large American cities, Haynie (2008) associates the mean length of road segments with a mean value of metric reach at 1 mile radius for different types of street networks. The resulting pair values are 100m-87km (330’-54mi) for a Colliding grid, 145m-69km (476’-43mi) for a regular grid, 159m-30km (521’-18.5mi) for a Super-Grid, 170m-46km (556’-28.7mi) for a Curvilinear layout and 188m-20km (618’-12.4mi) for a layout with Cul-de-sacs. The average value of our sample corresponds to the values found in the curvilinear type of grid with a similar street-segment length average. The point to make is not to say that Atlanta is made of a curvilinear type of fabric but that its behavior approximates the one of a curvilinear pattern. Atlanta is made of very different types of grids, the example of downtown Atlanta with its 126m-93km (413’-58mi) illustrates how it can diverge from the average values depending on the local configuration. In the literature, the metric reach of North American cities computed by Peponis, Allen et al. (2007) positioned Atlanta in the lowest end of the spectrum.

Directional Reach

[def.] Directional Reach records the total length of streets available from a street segment within a set number of changes of direction. What counts as a change of direction is given by a threshold angle. In this study an angle superior to 10 degree is considered a turn. Directional reach can be run with a different number of turns. Directional reach at 0 direction change depicts the "straightness" of the urban fabric locally. It is associated with legibility of urban structure. This is the only measure that does not take density into account; it is the simplest configurational measure.

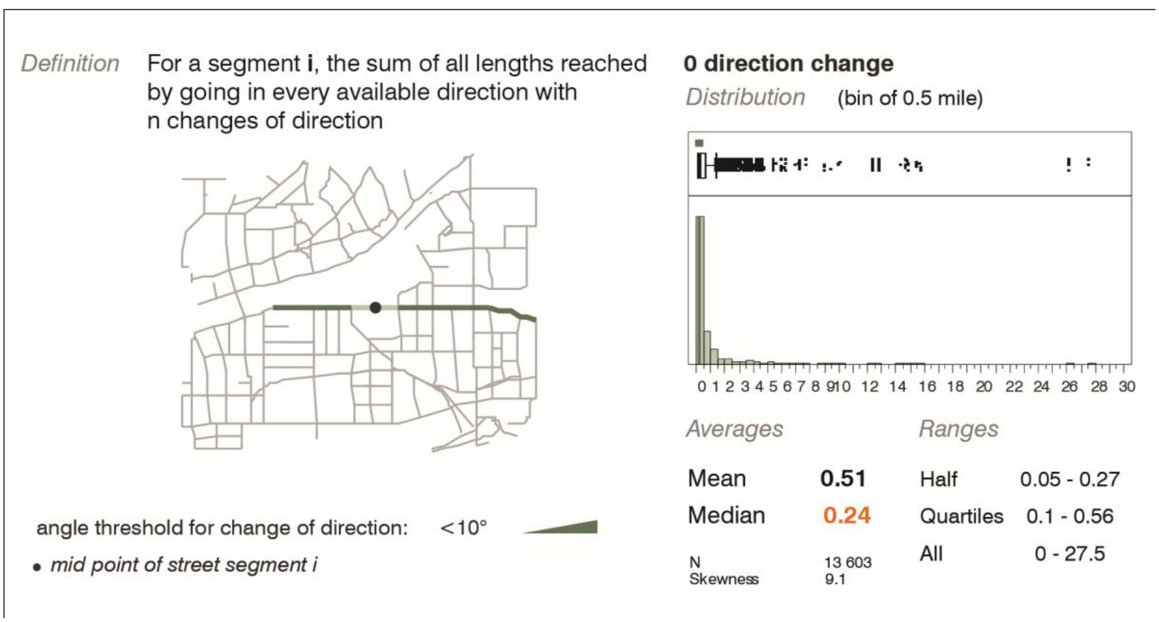

Figure 46. Directional Reach distribution for road segment with 0 change of direction to measure straightness of the street configuration (averages and ranges).

In Figure 46, the mean value is high compared to the median. For an average size of a block at 0.08 mile, the median value is 3 times the length of a mean block-face. Half of the data in its most compact form is located below this threshold. The straightness of the urban fabric is very localized. The highest values, above 5 miles, are attributed to interstates. Besides the highway system, the directional reach with no turn highlights the main streets of Atlanta that structure the city. Two behaviors are visible in the distribution by the highly positive skewness: first, lots of very local straight and short lines, and second, few very straight and long lines that produce a disconnected and sparse global structure. Of course, the presence of few long and many short lines is identified as a characteristic of street networks generally (Hillier 2002). In Buenos Aires the mean value is 1.18 miles for directional reach no direction change and 10 degrees angle threshold (Scoppa 2013). Thus, Buenos Aires is twice straighter than Atlanta, as a result of its regular square grid.

The values provided above are per road segment. The following Table 9 gives the mean reach values per Block that will allow future comparison with other measures that are associated with the block unit.

Mean Reach per Block

[def.] For each block, Mean Metric Reach per Block is the average value of all its faces. There is a transfer of data from street segment to block. Each street segment defines one or two blocks-faces on each of its sides. The reach value associated to each segment is transferred to one or two blocks. The mean reach value of blocks can then be associated with other measures linked to the block unit. In other words, Mean Reach value for a block tells the amount of available street network nearby. It attributes to the block unit the measure of connectivity potential (in miles).

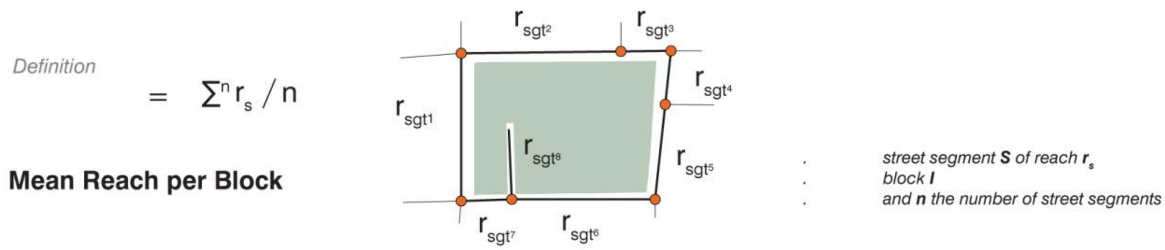

Figure 47. Mean reach per block is calculated as the mean of the road segments values associated to the block. It is not based on the block-faces.

Summary

Table 9. Averages and Ranges for metric and directional mean reach per block, local and global connectivity and straightness.

	units	*n*	*MEAN*	*MEDIAN*	*HALF*	*QUARTILES*	*ALL*
Metric Reach 0.17	*mile*	*4028*	0.96	0.9	0.58-1	0.7-1.2	0.25-2.8
Metric Reach 1	*mile*	*4028*	28.2	26.1	11.3-28.3	18.1-36.7	1.9-63.3
Metric Reach 5	*mile*	*4028*	751	793	790-972	633-888	223-978
Directional Reach 0dc	*mile*	*4028*	0.5	0.38	0.08-0.43	0.22-0.68	0-5

The translation from road segment to block shows an overall slight increase of the averages. The distributions follow the same trend. A block tends to be associated with 15 to 30 miles of street at 1 mile radius, and with 790-972 miles globally; 0.58 to 1 mile locally and 0.08 to 0.43 mile of straightness.

Correlation within measures of street load

The external load is represented by metric reach (0.5-1-5 miles radii) and directional reach 0 direction change. Table 1 reports the correlations between each measure by giving the r square value, the slope (or beta value) which shows the positive or negative relationship and the significance of the correlation.

Table 10. Linear fit between number of block-faces [nBF] and reaches with metric reach 5 miles [MR5], 1 mile [MR1], and 0.17 [MR0.17], with directional reach 0 direction change [DR0dc]. Coefficient of determination [r^2], slope with beta value [b], and significance with p value [p] are reported.

y / *x*	nBF			MR5			MR1			MR0.17		
	r^2	b	p	r^2	b	p	r^2	b	p	r^2	b	p
MR5	0.01	-3.5	<.0001*									
MR1	0.02	-0.3	<.0001*	**0.73**	11	<.0001*						
MR0.17	0.03	-0.01	<.0001*	**0.42**	312	<.0001*	**0.52**	27	<.0001*			
DR0dc	-	-	-	0.08	109	<.0001*	**0.1**	9.2	<.0001*	0.03	0.22	<.0001*

The number of block-faces has a negative relationship with all metric reach measures; as the number of block-faces increases the reach value decreases. While significant, the relationship is very weak. The fragmentation of the block boundary in multiple faces does not play an important role on its street connectivity, and if any, it tends to decrease it locally and globally. This highlights the role of internal streets in lowering connectivity for the large blocks.

The correlations between metric reach one mile is very high with both metric reach 5 miles (n=4028, r^2= 0.73, b=11, p<.0001) and metric reach 0.17 mile (n=4028, r^2= 0.52, b=27, p<.0001). To avoid auto-correlation in future analysis, metric reach at one mile radius is not included as a descriptor for the external load of blocks.

5.2 Internal Load: building configuration impact on the block boundary

Building footprints inside a block constitute its internal load. Looking at footprint configurations helps in determining the amount of space they take and how they are distributed on the block. First the internal load at the block level is given by the building coverage – how much of the ground is taken by building footprints – and by building fragmentation – how many distinct footprints are in this block. Then, the internal load is transferred onto the boundary by measuring how the buildings create an enclosure on the edges based on the amount of frontage and its fragmentation. Frontage is linked to a fixed distance from the block boundary. In addition, to capture buildings that are located further inside the block, a measure of setbacks is proposed. When the setback is deep, there is no direct building load on the block boundary and access can become indirect. In such cases the load can be interpreted as the lack of capacity for new buildings shallower towards the perimeter that would obstruct access to the prior buildings located at the back. It is followed by details on how these two aspects of the building load, frontage and setback, are measured in GIS.

5.2.1 Internal Building load [Block]

At first, the internal building load for a block comprises coverage and fragmentation of the overall building density.

Building Coverage

[def.] Building coverage is the proportion of land within a block occupied by building footprints (Moudon 1989). It is the ratio of the sum of areas of all building footprints located in a block by the area of this block. This is the most often used measure when dealing with building footprints. It is sometimes called "built area" (Urhahn and Bobic 1994). Building coverage indicates how much ground of the block is occupied by buildings. Surfaces of buildings located above or below ground level are not included. Building coverage measures building density at ground level and is also called "ground surface index" (GSI) or simply "coverage" (Berghauser Pont and Haupt 2002). Low values represent low density with zero indicating non-built blocks and a hundred indicating fully built blocks. Building density is an indicator of block behaviors: low ratio captures either underperforming block or block with potential (reserve of land). The distinction between underperforming or with potential is a matter of building configuration that will be addressed later.

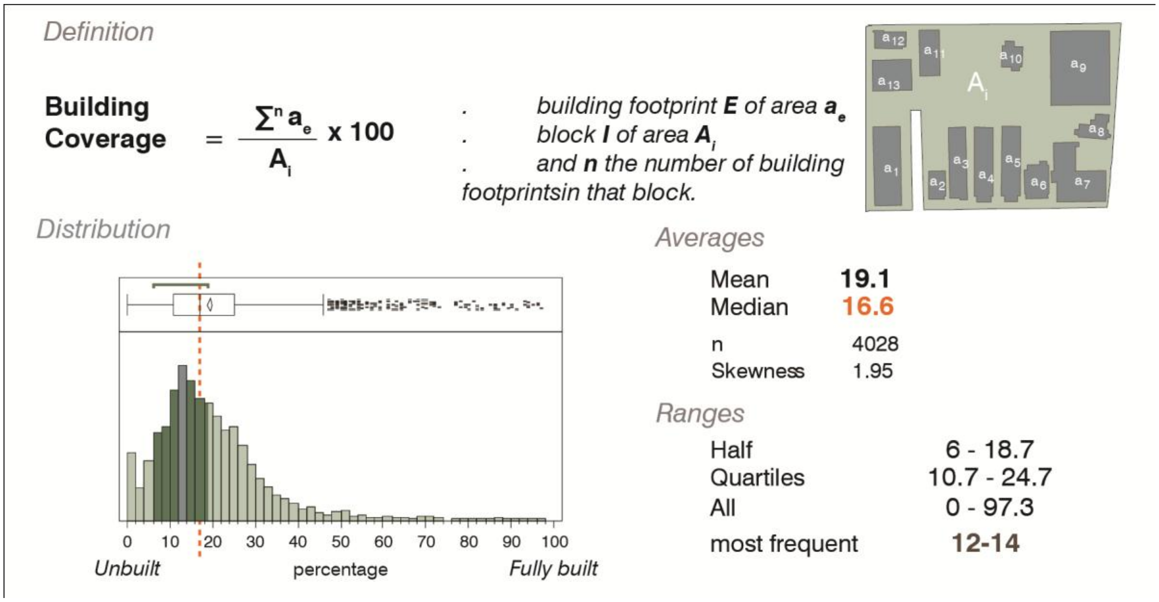

Figure 48. Definition and distribution of Building Coverage per block (averages and ranges) which is also the percentage of building area per block area.

The sample of blocks shown in Figure 48 is covered by building footprints for up to 97 percent of the surface. Fully built blocks are however very few. In average building footprints only take 19 percent of the block, with a median value of 17. The most frequent values are located below the average, therefore with a very low density. Non-built blocks represent a minor portion of the sample, only 3.6 percent. Building coverage distribution is skewed with a tail on high values. The frequency of block decreases as their building coverage increases.

Based upon the analysis of 530 blocks located on the busiest center of Tokyo – area of 2 by 2km – the building to Land ratio (BTL) ranges from 30 to 60 percent for residential zone and reaches the legal limit of 80 percent in commercial zones (Yoshida 2004). The average value of Atlanta by comparison is very low, and is definitely underperforming. However, for a more fair comparison, Urhahn and Bobic (1994) present percentage of site coverage, or the built-up ratio, in several neighborhoods that are more comparable. The “half-quartiles range” places Atlanta as comparable to 5 others neighborhoods: Saint-Quentin-en-Yvelines in Paris (20 percent), Tegeler Harbour in Berlin (15 percent), Dedemsvaartweg in the Hague (15 percent), Museum Park in Rotterdam (10 percent), Louisiana in Humlebaek (10 percent), Breukeleveen in Loosdrechtse Lakes (8 percent).

Building Fragmentation

[def.] Building fragmentation is the number of building footprints in a block. It indicates the fragmentation of the non-built space of a block. The density of building in a block gives a sense of the potential of the left-over space: if the block is very fragmented, only infill is possible; if the block is not fragmented there are more possibilities for arranging new buildings.

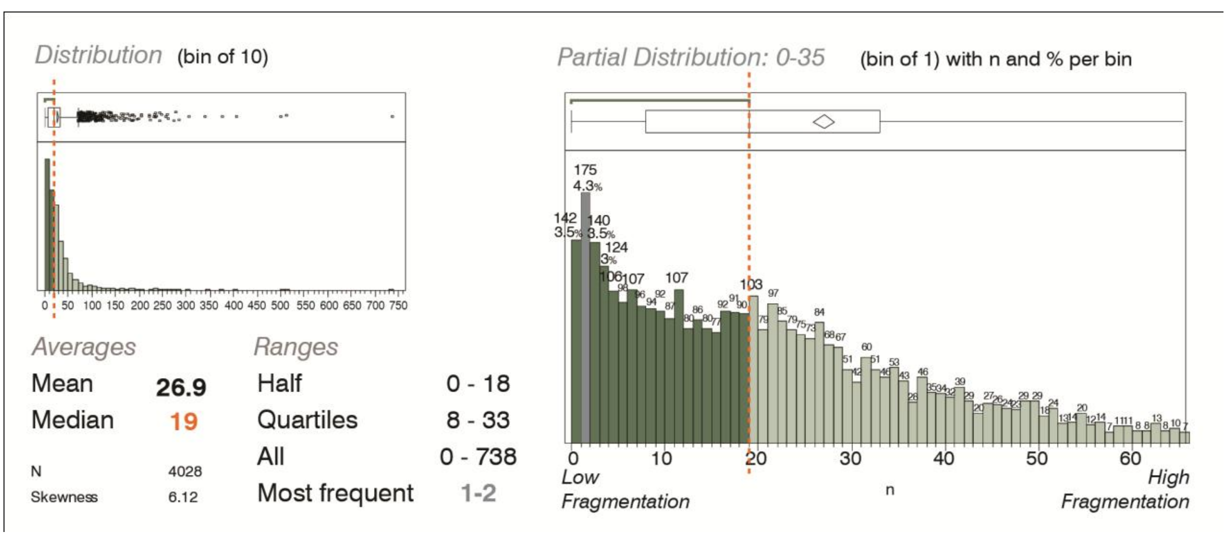

Figure 49. Full and partial distribution of number of building footprints per block, or building fragmentation (averages and ranges).

The number of building footprints per block in the sample ranges from zero to more than 700, for a total number of 108,451 footprints (Figure 49). The skewness of the distribution indicates the presence of very few blocks with very high number of building footprints. Only 7 blocks have more than 300 footprints, 50 blocks more than 150 footprints and 258 blocks with more than 70 footprints. One can consider the 7 blocks with more than 300 footprints as exceptional. Half of the sample is concentrated between 0 and 18 footprints per block, below the median and mean values. From these blocks only 142 are vacant and 175 have only one building footprint, respectively 3.5 and 4.3 percent of the entire sample. It is worth noting that the most frequent cases encountered are blocks with a single aggregate footprint.

Since a building footprint can actually represent several buildings, the measure of footprint fragmentation captures the process of aggregation whereby increasing building densities lead to increasingly fewer composite footprints and ultimately to a single composite footprint. A very low fragmentation can consequently be linked to high building coverage. The relationship between fragmentation and coverage is thus computed to test the effect of one upon the other.

Correlation between building coverage and fragmentation

The relationship between fragmentation and coverage describes footprint configuration in a block (Figure 50). The different combinations of values can be evaluated by comparison to four extreme configurations: a vacant lot (1), one large building that occupies the entire block (2), lots of buildings with low coverage (3) or lots of buildings with high coverage (4). In our sample, the plot shows no block in the latter category. This is partially explained by the fact that buildings in order to be isolated require some free space around them, and as a result more building footprints imply a decrease of coverage. High footprint coverage and fragmentation are difficult to combine in a block configuration.

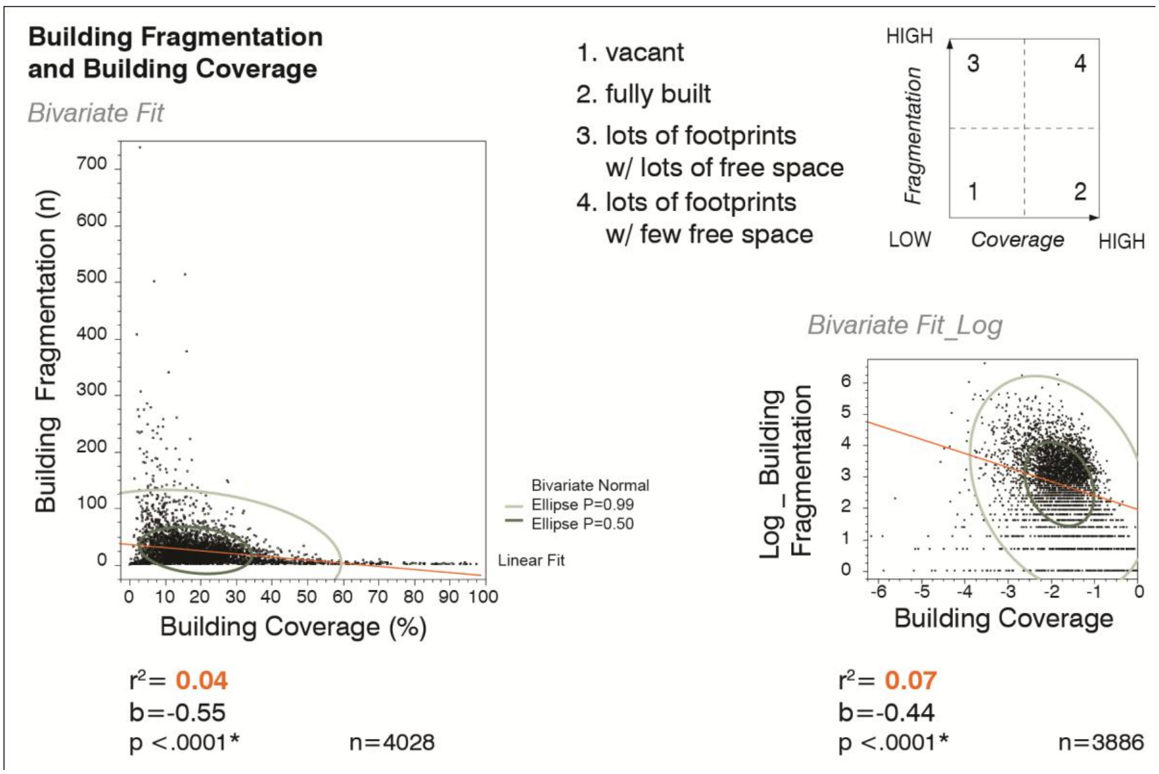

Figure 50. Correlation between Building Fragmentation and Building Coverage per block, logarithmic relationship and diagram of different pair combinations.

Building footprint fragmentation and coverage per block have a negative and weak correlation (n=4028, r^2=0.05, b=-0.55, p<.0001). Overall, as building footprint coverage increases, the number of footprints decreases. The block with the highest fragmentation has a very low coverage and the block with the highest coverage has only one building footprint. But their logarithmic relationship (n=3886, r^2=0.07, b=-0.44, p<.0001) shows that at first, the number of footprints increases with coverage, and then, past a certain threshold of building coverage, the number of footprints decreases. In other words, building footprints tend to aggregate when there is no more available space around buildings such that a new building and its required minimum surrounding space can no longer fit in; then, the new building is added against an existing one.

5.2.2 Building load at the edge [Block-face]

If building footprint coverage and fragmentation are indicators of the building density on the overall internal surface of the block, they do not indicate the relationship of the building footprints to the street network. The relation between street and building is often regulated by setbacks and the notion of frontage is important for the continuity of the built form as well as for economic reasons. The association of frontage with the potential for retail is the most common incentive to measure frontage, with the linkage between frontage and safety through "eyes on the street" being a close second[18]. But frontage also participates to the enclosure of the street[19] which is a desirable urban quality according to Ewing and Handy (2009). They present five main urban qualities:

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[18] The frontage of a block is of two kinds: the external frontage, which is at the periphery of a block and therefore easily accessible and the internal frontage, which corresponds to dead-ends which have a block-face on each side but one or several step away from the street network. This difference might impact the location of retail.

[19] Enclosure of the street is different from block enclosure that will be discussed later.

Imageability, Enclosure – which refers to *the degree to which streets and other public spaces are visually defined by buildings, walls, trees and other vertical elements. Spaces where the height of vertical elements is proportionally related to the width of the space between them have a room-like quality*[20] – *Human* scale, Transparency and Complexity – which uses the number of buildings on both sides of street to measure it in operational definition. Enclosure and Complexity are the qualities that this research is focusing on.

Measures of building frontage by block-face (in GIS) are presented in some available research (Smith, Nelischer et al. 1997) to analyze the effects of urban design quality upon walkability and therefore health. However, measures are applied to small samples without complex block shapes. The variation of building frontage is due to the setback of buildings relative to the plot boundary line. New Urbanists made a case for Form-based zoning ordinances that include buildings standards for setbacks and building lines requirement (RBL) to insure a continuous frontage such as implemented in Arlington, Virginia (Cherry, Deakin et al. 2006).

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[20] Extract: "*Previous attempts to operationalize: The visual assessment literature suggests that enclosure is an important factor in human responses to environments, and that solid surfaces are the important variable in impressions of enclosure. Using photographs of Paris, Stamps & Smith (2002) found that the perception of enclosure is positively related to the proportion of a scene covered by walls, and negatively related to the proportion of a scene consisting of ground, the depth of view, and the number of sides open at the front. […]However, when it comes to operationalizing the concept of enclosure, urban design guidelines tend to limit themselves to one aspect of enclosure, the relationship between street width and abutting building heights. […] As a general rule, the tighter the ratio, the stronger the sense of place. (City of Raleigh, 2002) Maximum setback limitations in certain zoning districts of progressive jurisdictions (for example, New York, Seattle and San Francisco) seem aimed in part at creating a sense of street enclosure. Similarly, required building lines (build-to requirements) in the new form-based codes may have this purpose (Arlington, VA; Woodford County, VA; Pleasant Hill BART Station Property Code).*"

Frontage and Setback: method in GIS

The two techniques of attaching building data, block data and street data are the following: the offset method based on the notion of frontage and block-face and the radial method based upon depth. The offset method starts from the principle that street segments are flanked by buildings on each side. In our GIS database, successive offset distances from the street segment layer have been computed in order to reach the building footprints. Buffers are created by the offset on both sides of the segment by increments of 5 meters (5-10-15-20-25-30) that are then intersected by the building footprint layer. The 5 meters buffer captures very few buildings and describes very narrow streets only. The full extent of the "block enclosure" is made legible when the 30 meters buffer is used (Figure 51).

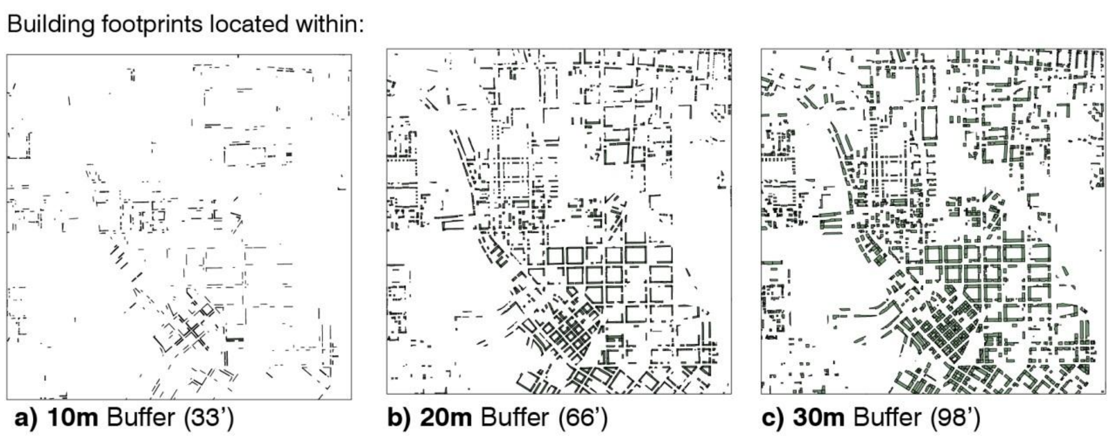

Figure 51. Offset method with: a) a 10 meter buffer from the road centerline, b) a 20 meters buffer and c) a 30 meters buffer that capture the amount of building footprints within each buffer.

Talen (2003) defines the "enclosure of the block as "*the 'volumetric' of the city*". She draws the limit at 9-14 meters (30 to 45') in the interior of the block from the street (Talen 2005) for the sense of enclosure to be effectively present. In the case of Atlanta, the chosen distances are 20 meters and 30 meters (100') from the centerline of the street (Figure 52). With an average of 8 meters for a half street width, the distance is reduced to 12 meters (72') for the 20m-buffer and 22 meters (98') for the 30m-buffer. Both distances are higher than Talen's proposed distance for the feeling of enclosure.

The building footprints intersected by the buffer area define the base for frontage[21]. One of the limitations of the offset method is that several buffers can overlap onto a single footprint.

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[21] Most streets have two sides, two block-faces. But exceptions exist for street segments located on the edge of the sample which have data for only one side and highway segments that are treated as block-face on only one side.

Figure 52. Representation in GIS of Enclosure by " Building frontage" resulting from the intersection of a 30m buffer on both side of road centerlines (b) and Building footprints (d) and their relationship to block (e) and building footprint (f)

[Radial method] Setback

The radial method focuses on the distance between the center of the block and the boundary. Figure 53 shows the sequence that creates radials for setbacks. Radials are drawn from block-centroids to road centerline first, then clipped by the block boundary to produce the block radials and finally by the building footprints to produce the non-built part of the radial. On this last step, only the radials that are in contact with the block boundary are kept to represent the setbacks. The points of intersection between the setback radials and the block boundary determine the block-faces to which a footprint is assigned (appendix D).

Figure 54 shows how the unique identifier of each element is in relation to the block-face identifiers. These are only the graphic representation of frontages and setbacks. Their computation per block and block-face is further explained, starting with the building frontage.

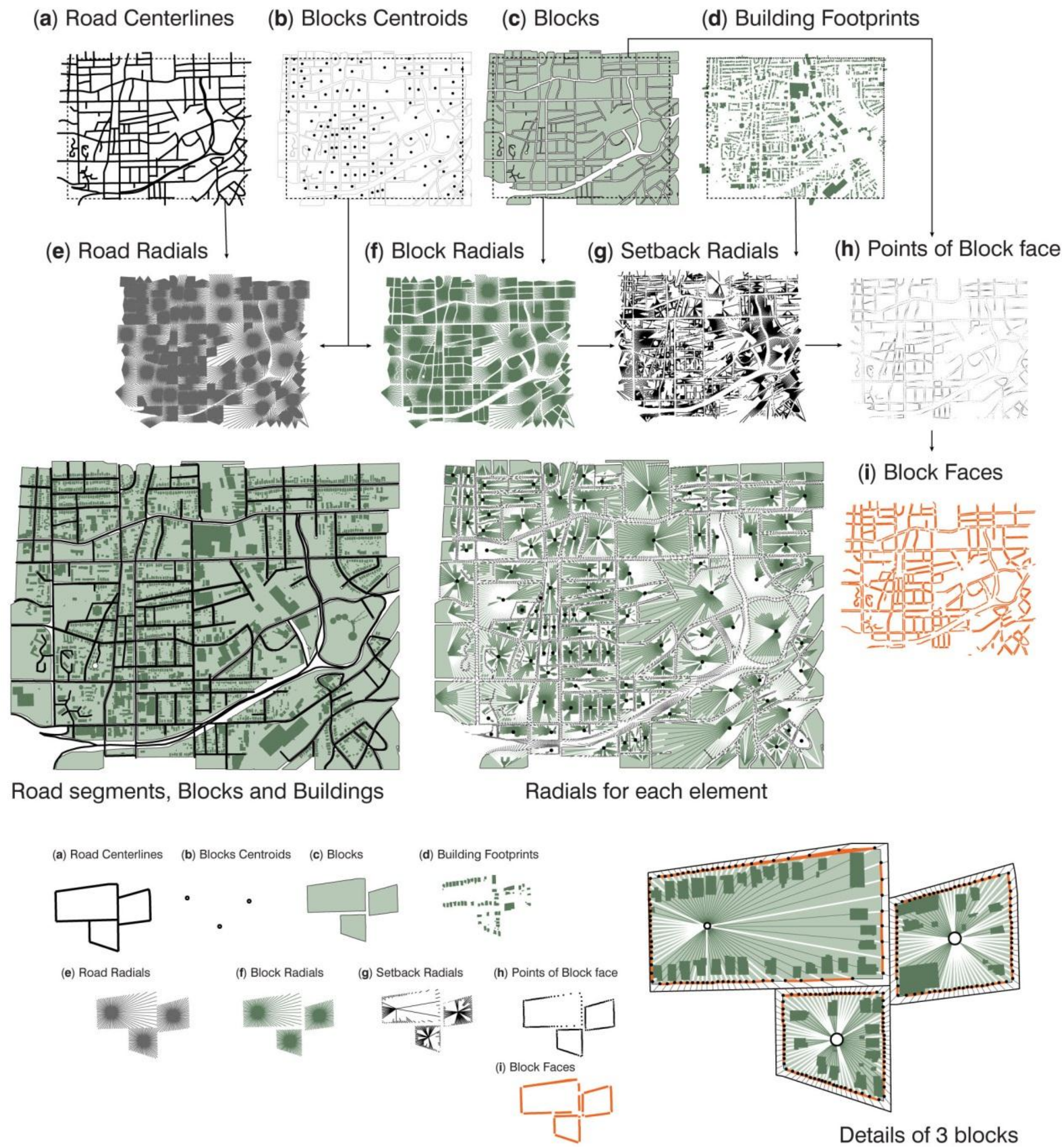

Figure 53. Sequence for radial method to link block to street to block-face, as well as calculating setbacks as the part of the radial that links the block boundary to the first line of building footprints or centroids.

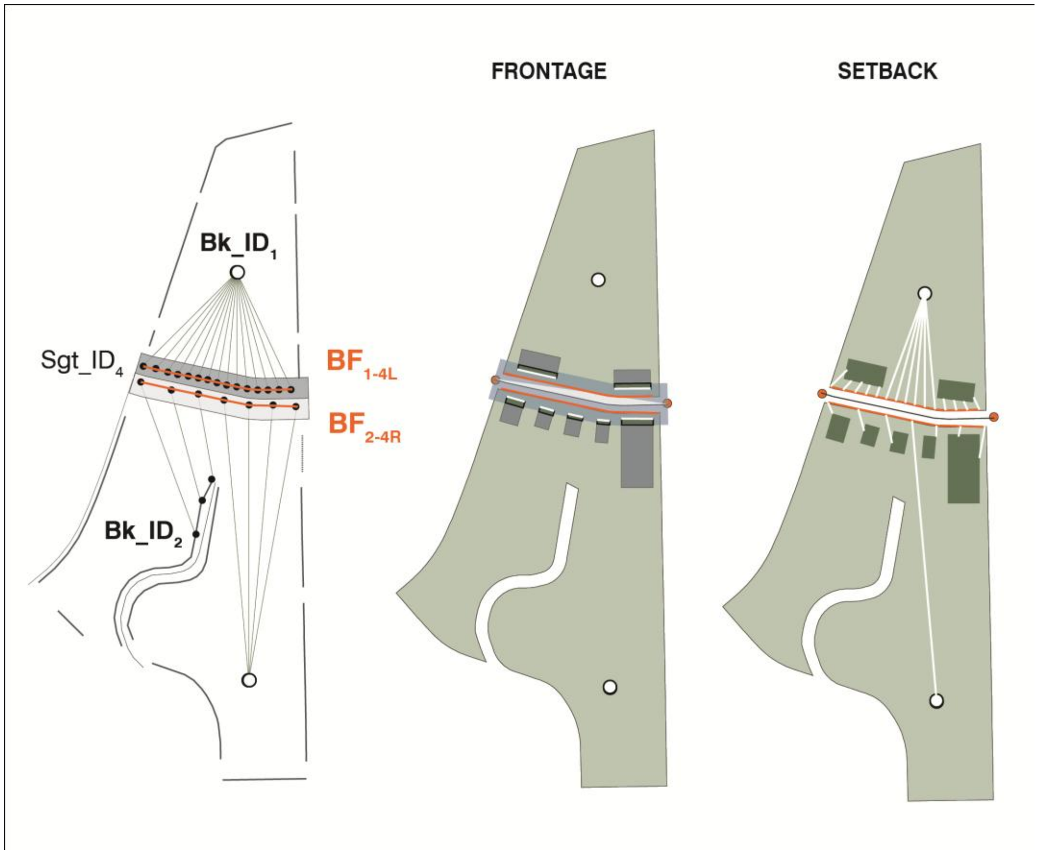

Figure 54. Detailed version of both frontage and setback graphic relationships for 2 block-faces [BF].

Building frontage

[def.] Building frontage is made of the lines of the building footprint that are within a given distance from the centerline of the street. It is calculated by the buffer method in GIS. As shown in Figure 55, the building footprints fully or partially contained within the 30 meters buffer are counted as part of the building frontage. The smallest minimum bounding rectangle [SMBR][22] simplifies their shape in a rectilinear representation (Figure 55-upper graph). Their width gives an approximation of the frontage[23]. The building frontage associated to a block-face is sum of all the building SMBR widths divided by the length of the road segment.

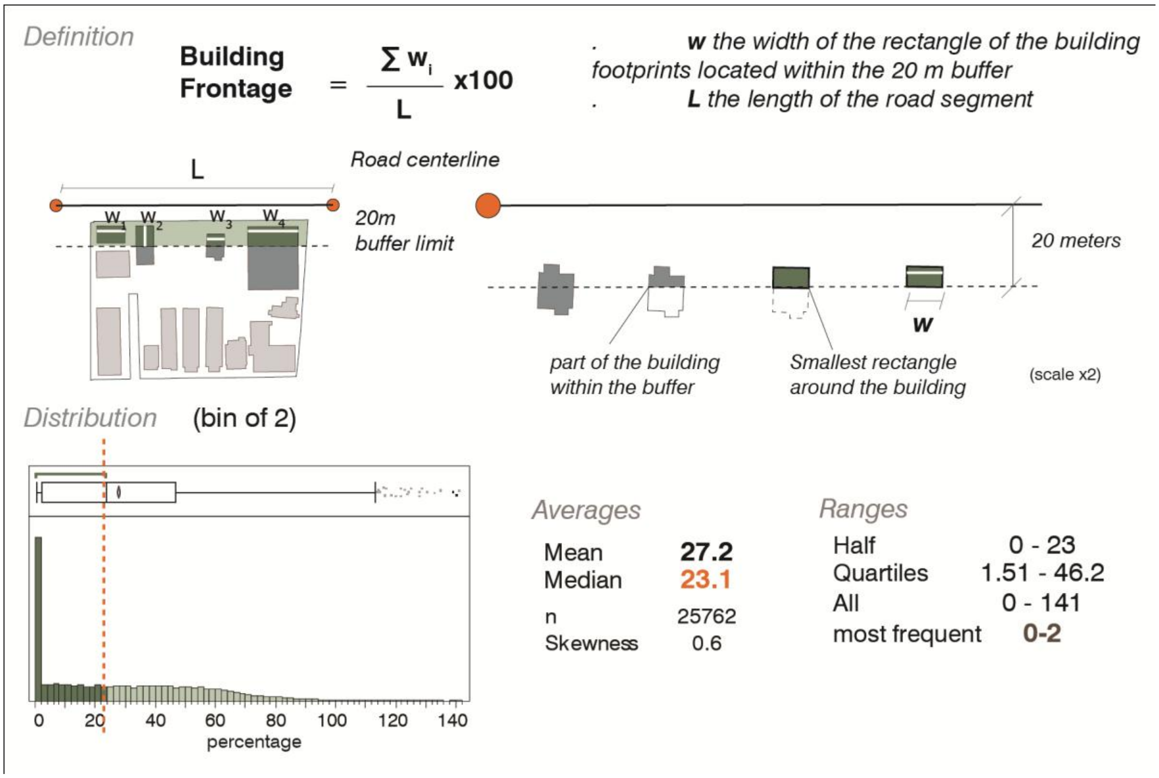

Figure 55. Definition and distribution of Building Frontage per Block-Face at a 20 meters distance from the road centerline, with averages and ranges.

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[22] In Regnauld (1998), orientation of building is defined by the "general orientation segment" or by the "perpendicular segments of 2 main direction of walls". Based on GIS logic, five measures are proposed: longest edge (Ruas 88); weighted bissectors (Regnauld 98, p.72); 2 longest diameters and their average direction weighted each by the length of the line; and the smallest MBR with the longest side of the rectangle (Mats Bader from AGENT project).

[23] Errors arise when the largest dimension (width) is perpendicular and not parallel to the street. But with the 30 meters buffer limit, the margin of error by including only parts of very large building is limited.

The most frequent case encountered does not have any frontage within the 12 meters zone from the perimeter of the block (20 meters buffer). A quarter of the block-faces have around 25 percent of frontage built. One out of four block-faces remains unbuilt on its first 12 meters. Block-faces exceeding 100 percent frontage are those with several small narrow buildings as exemplified in Figure 55 with the 'building 2'. Its width w_2 is not the longest dimension of the SMBR; as a result the frontage taken into account is the dimension perpendicular to the road segment. With a buffer at 30 meters – 22 meters from the block boundary – the percentage of unbuilt block-faces drops to 12 percent. The average built-up frontage per block-face is now 46 to 47 percent[24]. The next step is to associate frontage to the full block to measure its overall enclosure.

<u>Block Frontage Ratio (or building enclosure)</u>

[def.] The building enclosure ratio of a block is the ratio of the total length of building frontage by the perimeter of a block. It is calculated by sum of frontage length divided by block perimeter multiplied by 100.

[24] The margin of error is greater; the amount of buildings that are included in the 30 meters buffers is deeper. As a consequence the amount of frontage can reach 350%, three times its actual dimension.

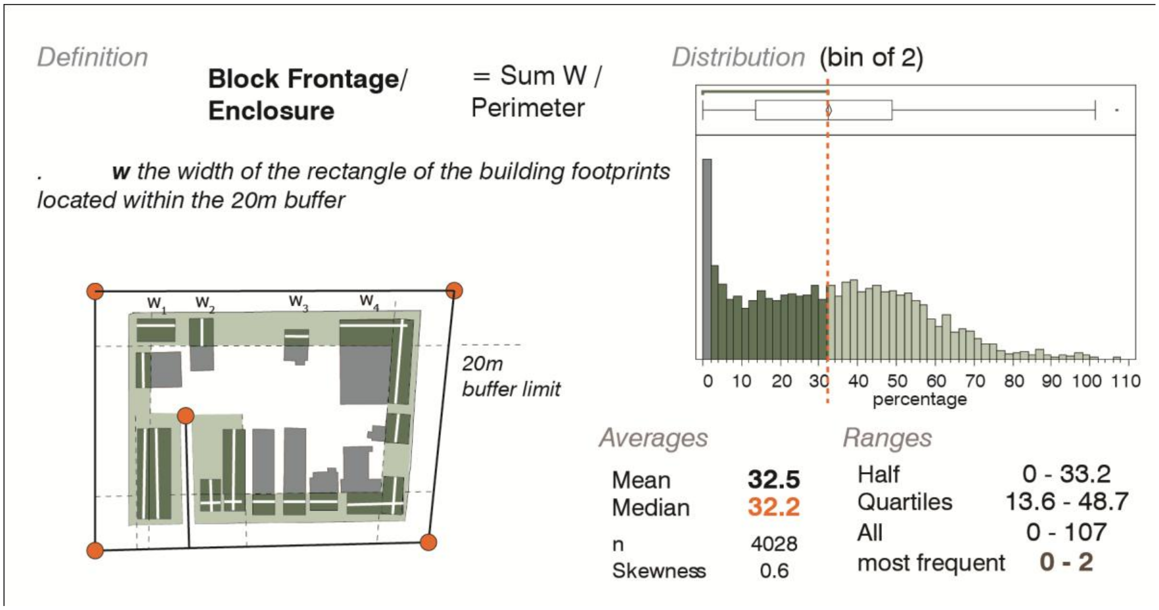


Figure 56. Definition and distribution of <u>building frontage/enclosure per block</u> at a 20 meters distance from the road centerline, with averages and ranges.

366 blocks have no building frontage (9 percent of the sample), and half of the sample has no more than one third of its perimeter built (Figure 56). If the buffer distance is increased by 10 meters (and the distance from the centerline of the road segment equals 30 meters), the amount of building enclosure increases to reach half of the perimeter (52.2 percent mean and 53 percent median). The number of blocks without any frontage at 30 meters (22 meters from the parcel line) drops to 154 (more than half of the 366 blocks without any frontage at 20 meters). The variation of enclosure at 20 and at 30 meters indicates that building footprints in Atlanta tend to be located deep from the edge of the block. Block enclosure measures the percentage of built frontage. However,

enclosure can also be described quantitatively according to its fragmentation as is discussed next.

Building Enclosure Fragmentation

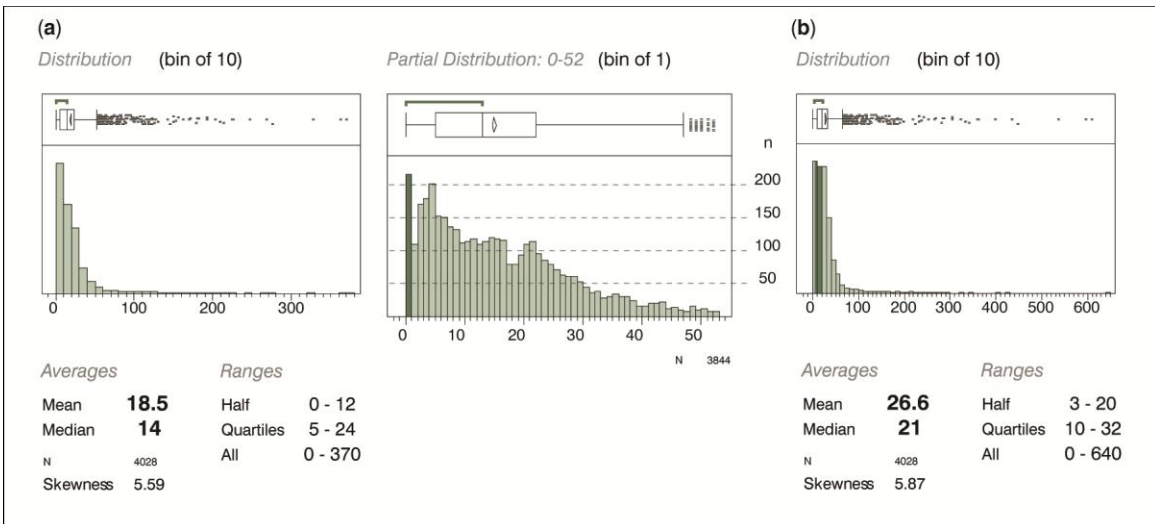


Figure 57. full and partial distribution for frontage fragmentation of blocks at 20 meters (a) and at 30 meters (b) with averages and ranges.

The number of building fronts that makes the frontage tells how fragmented the experience is for the passerby (Figure 57). 215 blocks do not have buildings within 20 meters from their edges and 147 do not have any buildings within 30 meters. Blocks without building on their edges are the most common type of blocks. If one disregards the non-built blocks, the most recurrent number of buildings (4 percent of the sample) that makes up the block-frontage is 4 for a 20 meters buffer. At 30 meters, there are two peaks in the histogram at 4 buildings and 26 buildings (4 percent for each category, which represents around 150 blocks in each category).

<u>Correlation between building enclosure and enclosure fragmentation</u>

The correlation between frontage ratio and fragmentation shows that for frontage values between 60 and 70 percent of the block perimeter there is a great variation of fragmentation at the edge: 1 to 50 building footprints are present (based on the 30 meters buffer). If the frontage of the block is built up to between 50 and 60 percent, the number of building footprints ranges from 1 to 46 (based on the 20 meters buffer). The important conclusion is that the values of 50 and 60 percent frontage enclosure represent a threshold where the frontage is saturated by buildings and the phenomenon of building aggregation starts to happen, leading to some small values of fragmentation. It is similar to the logic of building coverage and building fragmentation, described earlier.

5.2.3 Building load from the center to the edge [Block Depth]

Even where the continuity of buildings that would form the "volumetric" of the city whished by Talen is not achieved near the block face, so that enclosure is absent, another type of analysis can address the latent configurational patterns in the sample of blocks. The analysis of setbacks captures the variation of conditions that occurs from the center of the block to its edge. It tells if a block is built on its interior, and how far inside.

Setback

[def.] Setbacks are the distance from the limit of the lot and the street to the first line of the building footprint. In this sample, setbacks are represented by radials. Where a radial intersects no building footprint, it measures the distance from the perimeter to the centroid of the block. When it intersects a building footprint, the portion of the radial lying between the perimeter of the block and the footprint becomes a measure of setback as illustrated in the upper part of Figure 58. Quite simply, radial setback indicates the ratio of "in front of the buildings" length and the "behind the building façade" length as one moves from the perimeter to the block center.

As the setback ratio represents the location of the first line of building in proportion to the distance from the perimeter to the centroid of the block, 50 percent means that the first line of the building footprint is located half way between the perimeter and the center of the block. 100 percent corresponds to places without any building; therefore values close to 0 tells that the building is located at the boundary, without any setbacks. The setback ratio per block is an average value of all the radial ratios (Figure 58).

There are a lot of non-built portions of blocks represented by a setback value of a hundred. The most recurrent value is 40 percent and half of the sample is located between 27 and 48 percent, which indicates location of the first building line fairly deep in the block. Buildings are placed between one third and half way the distance from the edge to center of the block. The distribution on both sides show that there are few blocks with little setback (extreme left) and few with buildings located in the center of the block (extreme right excluding the value of 100).

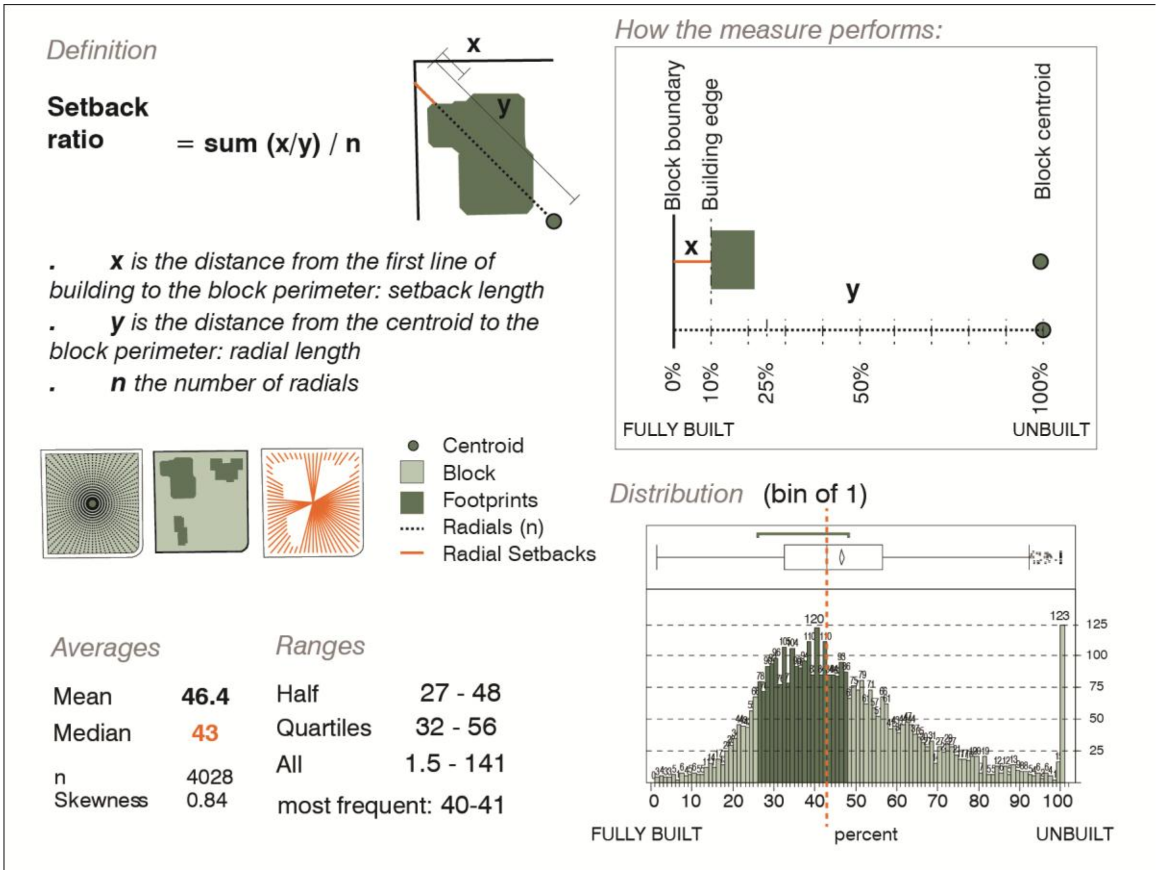


Figure 58. Definition and distribution of setbacks ratio per block (averages and ranges).

It is interesting to look at the average setback distance with non-built radials removed which is equivalent to measuring the average setbacks for buildings. The mean setback distance is 25 meters while the median value drops to 15 meters. With outliers removed – above 50 meters – 0-2 meters is the second peak on the histogram, the main peak is at 13-15 meters.

Table 11. Averages and ranges of internal building load per Block according to: building coverage [BC], frontage ratio at 20 meters [F20R] and at 30 meters [F30R], setbacks [SK], building fragmentation [BFg], and frontage fragmentation at 20 meters [F20F] and at 30 meters [F30F].

		n	*MEAN*	*MEDIAN*	*HALF*	*QUART.*	*ALL*
BUILDING LOAD	[BC]	*4028*	19.1	16.6	6-18.7	10.7-24.7	0-97.3
	[F20R]	*4028*	32.5	32.2	0-33.2	13.6-48.7	0-107
	[F30R]	*4028*	52.1	53	30.5-68	32.8-70	0-155
	[SK]	*4028*	46.4	43	27-48	32-56	1.5-141
	[BFg]	*4028*	26.9	19	0-18	8-33	0-738
	[F20F]	*4028*	18.5	14	0-12	5-24	0.37
	[F30F]	*4028*	26.6	21	3-20	10-32	0.640

Only 118 blocks are fitting all conditions of the internal load from building given by the 'half' sample range. They are illustrated in Figure 59.

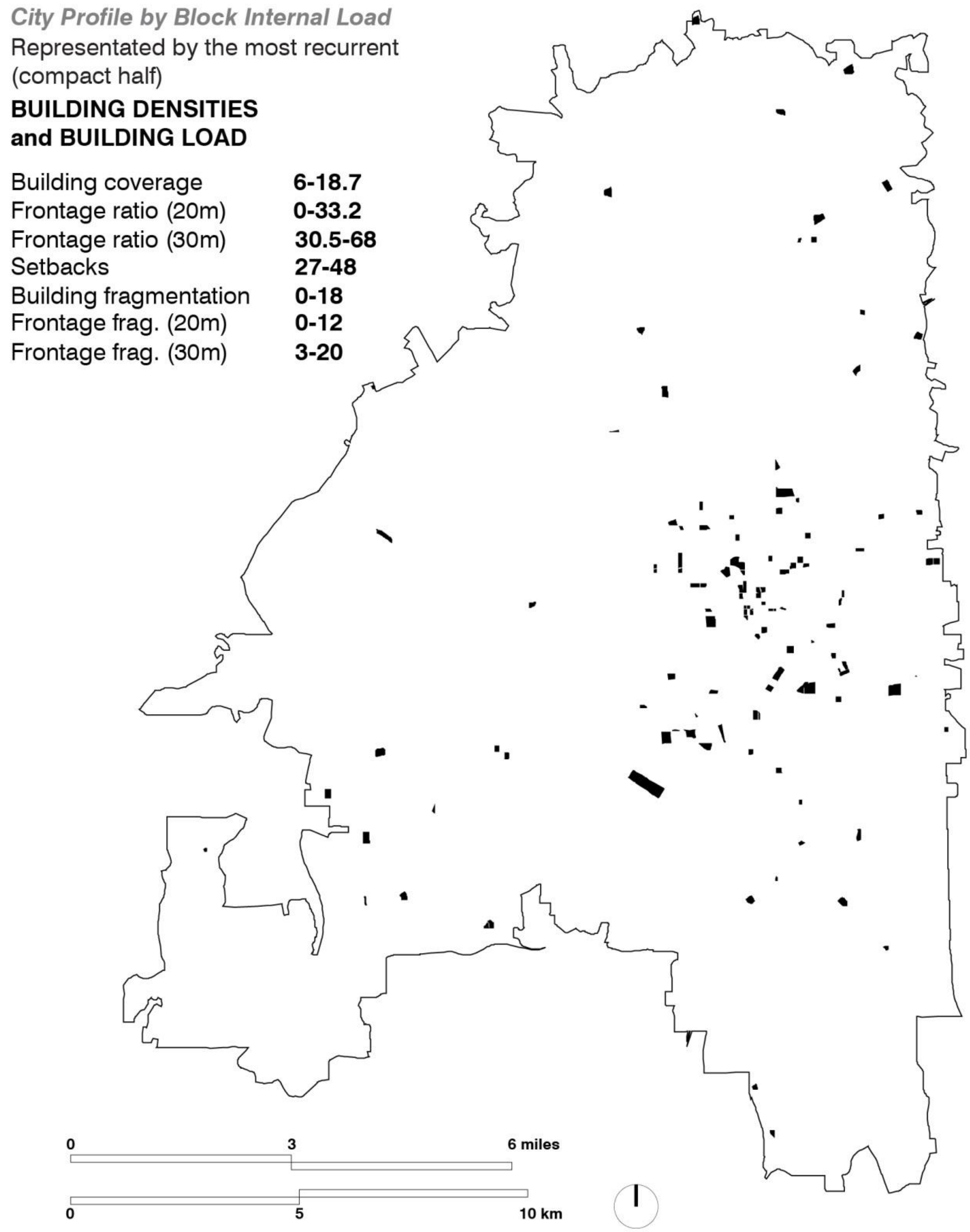


Figure 59. Blocks representative of Atlanta based on their internal load (mean): building coverage [BC], frontage ratio at 20 meters [F20R] and at 30 meters [F30R], setbacks [SK], building fragmentation [BFg], and frontage fragmentation at 20 meters [F20F] and at 30 meters [F30F]. They represent the compact half range (n= 118).

Correlation within measures of building load

The relationship between building coverage, building setbacks and building frontage follow the following trends.

Table 12. Correlation between measures of building load per block (mean): building coverage [BC], frontage ratio at 20 meters [F20R] and at 30 meters [F30R], setbacks [SK], building fragmentation [BFg] and frontage fragmentation at 20 meters [F20F] and at 30 meters [F30F]. Coefficient of determination [r^2], slope with beta value [b] are reported.

		BUILDING LOAD											
	y	Log_BFg		F20R		F20F		F30R		F30F		SK	
	x	*r^2*	*b*	*r^2*	*b*	*r^2*	*b*	*r^2*	*b*	*r^2*	*b*	*r^2*	*b*
BUILDING LOAD	BC	0.17	-0.03	**0.40**	0.90	0.01	0.02	0.32	1.01	.	.	0.40	-0.90
	Log_BFg			.	.	0.22	1.01	0.03	3.5	0.38	1.58	**0.09**	-4.52
	F20R					**0.39**	0.08	**0.79**	1.12	**0.16**	0.06	**0.42**	-0.65
	F20F							0.40	6.17	0.76	1.04	**0.25**	-3.94
	F30R									0.32	0.07	**0.57**	-0.60
	F30F											**0.28**	-3.50

Building coverage is positively correlated to frontage enclosure at 20 meters (n=4028, r^2=0.40, b=0.9, p<.0001), and 30 meters (n=4028, r^2=0.32, b=1.01, p<.0001), as well as negatively correlated to setbacks (n=4028, r^2=0.40, b=-0.9, p<.0001). It is negatively correlated with the fragmentation of the block (n=3886, r^2=0.17, b=-0.03, p<.0001), and positively but weak with frontage fragmentation at 20 meters (n=4028, r^2=0.01, b=0.02, p<.0001). The increase of the coverage of building footprints is linked to more construction at the edge as well as smaller setbacks.

In Atlanta, more building fragmentation[25] correlates with an increase of building frontage at 30 meters (n=3886, r^2=0.03, b=3.5, p<.0001) but the relationship is weak. Building fragmentation implies buildings located closer to the boundary (n=3886, r^2=0.09, b=-4.52, p<.0001) and less building coverage. Thus, a fragmented block will have a lot of building footprints and have a large void in its center; an example would be a very large block with single-family houses located as the edge of the block at very close intervals. This, in fact, is the most common building configuration in Atlanta.

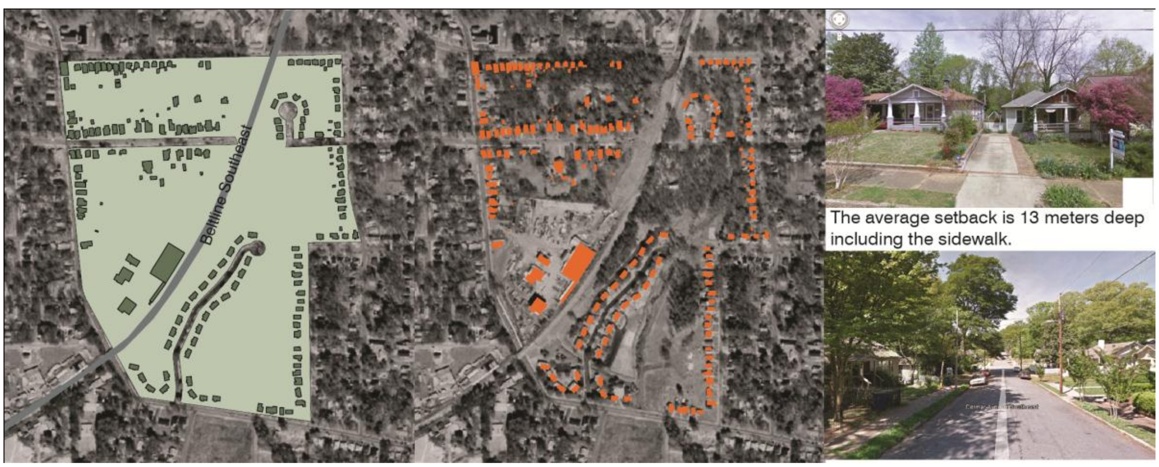


Figure 60. A block, as built in 2000, in the vicinity of Grant Park. It illustrates blocks with high frontage/enclosure, high fragmentation and low coverage.

In the block illustrated in Figure 60, the center is occupied by a railroad that is not functioning anymore. All single-detached houses are located at the edges and in a fairly

[25] The correlation is calculated with the log of the number of building footprints per block.

dense pattern. 173 footprints cover only 7.8 percent of the block ground, to create a frontage for 40 percent of the block boundary (frontage fragmentation is 6.2) with an average setback of 43 percent. The mean depth of the setback is 63 meters which results from the mean radial depth of the block 206 meters and the fixed setback in front of the house which is 18 meters from the street centerline.

Setback ratio drops as frontage ratio increases: high frontage induces building near the edge with smaller setbacks ($n=4028$, $r^2=0.42$, $b=-0.65$, $p<.0001$ at 20 meters and $n=4028$, $r^2=0.57$, $b=-0.60$, $p<.0001$). High frontage correlates positively with fragmentation ($n=4028$, $r^2=0.31$, $b=0.07$, $p<.0001$). This means that the growth of the frontage is by addition of new discrete footprints rather than the expansion of pre-existing ones.

5.3 Block behavior: a matter of Size and Shape?

This section clarifies the relationships of the external and internal loads with the block size and shape. While building footprint densities, i.e. building fragmentation and coverage, have shown little correlation with each other, is there a specific type of block that achieves greater footprint density? Do the size and shape of blocks facilitate one or the other or both? The two most representative relationships revealed by the analysis of this sample are: first, the presence of small, compact and regular blocks with little footprint fragmentation and high coverage; and second, large blocks with a meandering boundary with lots of buildings footprints but a very low coverage.

Correlation: Building Densities with Block Size

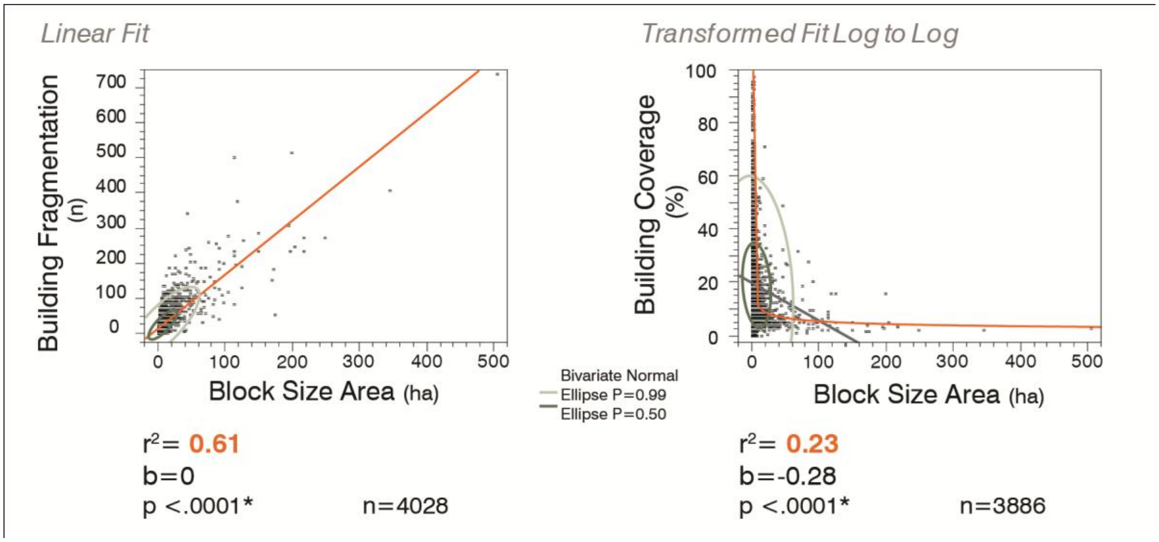


Figure 61. Correlation between block size and building densities. Coefficient of determination [r^2], slope with beta value [b], and significance with p value [p] are reported.

When blocks are larger, the number of footprints increases. There is a strong correlation between the two variables (Figure 61). But block size and building coverage have a negative logarithmic relation. As blocks become larger their coverage decreases. The correlation accounts for only 23 percent of the variance of coverage (n=3886, r^2=0.23, b=-0.28, p<.0001) as compared to the 61 percent of the variance of the number of footprints (n=4028, r^2=0.61, b=-0.28, p<.0001). As blocks decrease in size, building coverage increases while the number of building footprints decreases. The main trend is as follows: as blocks get increasingly covered by building footprints, their number decreases, while simultaneously blocks tend to get smaller.

Table 13. Correlations between block characteristics (size: Block area, and shape: square compactness and Elongation) and their building density (building fragmentation and building coverage). Coefficient of determination [r^2], slope with beta value [b], and significance with p value [p] are reported.

			SIZE	SHAPE	
			Block area	*Square Compactness*	*Elongation*
BUILDING DENSITY	*Building fragmentation*	r^2	**0.61**	**0.28**	0.04
		b	0	-85.7	-68.5
		p	<.0001*	<.0001*	<.0001*
	Building Coverage	r^2	**0.23**[1]	0.07	0.04
		b	-0.28	16.5	26.1
		p	<.0001*	<.0001*	<.0001*

[1]log to log

As blocks become more irregular, coverage drops and number of footprints increases (Table 13). The increase of building fragmentation for irregular blocks can be explained by: (1) the increase of available "boundary", or perimeter, combined with (2) the need to "customize" the location of buildings, because of the block boundary is meandering; buildings need to adjust to the shape.

The relationships between the block characteristics – its morphology and building density – to the building and street loads on the block boundary show that the overall characteristics of blocks do impact the behavior on their boundary.

Table 14. Correlation between size (log_Area), shape (square compactness and Elongation index) and building densities (fragmentation and coverage) per block to street and building loads. Frontage fragmentation [F20F] and ratio [E20R] at 20 meters and setback ratio [SK] account for the internal load of the block. Reaches with metric reach 5 miles [MR5] and 0.17 mile [MR0.17], with directional reach 0 direction change [DR0dc] account for street load. Coefficient of determination [r^2], slope with beta value [b], and significance with p value [p] are reported

			SIZE	SHAPE		BUILDING DENSITY	
			Block area (log)	*Square Compactness*	*Elongation*	*Building fragmentation (log)*	*Building Coverage*
BUILDING LOAD	F20R	r^2	**0.10**	0.05	0.04	0.002	**0.46**
		b	-5.42	23	40.9	-0.8	1.1
		p	<.0001*	<.0001*	<.0001*	0.0068*	<.0001*
	F20F	r^2	**0.20**	**0.20**	0.02	**0.35**	0.005
		b	8.15	-48.1	-32.11	12.2	-0.12
		p	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
	SK	r^2	0.01	0.03	0.02	0.08	**0.41**
		b	-1.77	-15	-23.3	-4.19	-0.92
		p	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
STREET LOAD	MR5	r^2	**0.13**	0.06	0.03	**0.10**	**0.24**
		b	-47.8	185	278.8	-46.9	6.01
		p	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
	MR0.17	r^2	**0.32**	**0.12**	0.07	**0.24**	**0.22**
		b	-0.15	0.56	0.87	-0.15	0.01
		p	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
	DR0dc	r^2	0.004	.	.	0.003	0.01
		b	0.02	.	.	-0.02	**0**
		p	<.0001*	.	.	0.0001*	<.0001*

5.4 Discussion

Some links between external and internal loads with block size and shape have been presented in Table 14. 1) Building footprint fragmentation relates more with local than global connectivity. Less connectivity is linked to more fragmentation. 2) Building footprint coverage correlates positively with local and global connectivity, negatively with setbacks and positively with frontage. More connectivity is linked to more coverage, less fragmentation and higher amount of frontage. 3) High frontage fragmentation on the block boundary is linked to a high number of building footprints; this is an expected relationship but, surprisingly, it is not so strong. 4) Setback distances increase with large, irregular and elongated blocks; also when the building footprint disposition combines low coverage and low fragmentation. Only building footprint coverage has a strong impact on setbacks. 5) Overall local connectivity has a stronger relationship to block size and shape. It is also strongly linked to building footprint density. Global connectivity while is less correlated strongly correlated than local connectivity, but the relation remains significant. 6) The measure of straightness does not have a strong impact.

Therefore, if to achieve a highly built frontage, it is more likely realized through small, regular, and condensed blocks that also have higher connectivity locally and globally. Usually a designer will design blocks with such characteristics, however the existing state of the city shows a very different set of blocks.

CHAPTER 6

TYPOLOGICAL ATLASES OF BLOCKS AND BLOCK-FACES

The grouping of morphological elements such as urban blocks into classes is a way to show homogeneous patterns within a data set and explore their relationship to other types of “external” data, such as land use or population density. Classification aggregates discrete data into categories with can subsequently become associated with specific considerations, requirements or solutions regarding city planning and design. Classification is often applied to arrive at typologies of streets, blocks and buildings (or sets of buildings) considered in their own right. However, a typology of urban form would be richer if based on more than one of these elements. The difficulty is to find systematic linkages between their properties. In the absence of linkages any attempt to produce a typology that takes into consideration blocks, streets and buildings would result in too many classes and would not support a better understanding of urban form. The issue, then, is to present similarities, co-variations or contingencies in a meaningful and legible manner so that the resulting typology of urban conditions can support planning or design actions.

The typologies proposed here are contingent upon the selection of the properties used as inputs for the analysis. The selection of properties is driven by normative intent. The intent is to represent and characterize urban units according to numerical profiles and to group them into clusters. As a second step, clusters are depicted on maps to produce typological atlases. Typological atlases simply turn statistically derived clusters into maps using colors to mark the areas covered by the elements of each cluster. They serve to assess existing urban conditions or test future urban conditions.

Three typological atlases are proposed. The first concerns the morphology of blocks; blocks are described by their properties of size and shape. The second classification is established by street load and then by building load. These loads characterize and assess the existing conditions for the street network surrounding a block and the building configurations on it respectively. The resulting atlases highlight the pattern of sprawl in parts of Atlanta and the prevailing types of building configuration - essentially low density with fragmented building stock - and street patterns. The latter often entail internal access cul-de-sacs whose relative weight within the street network can be quite striking.

The Atlases help visualize the persistent building and street patterns and facilitate the evaluation of urban conditions so as to distinguish between saturated areas and areas with greater potential for future development. Given an urban form with very low building density, it is essential to concentrate the efforts of urbanization to the most promising places. The clustering of block-faces, more particularly, highlights potentials with respect to both the connectivity of streets and the continuity of building frontage. Block-faces are treated as indexes that help us assess the blocks' contribution to the global dynamic of the city. They are also the elements from which the sense of continuity of urban form is built up. The methods and evaluations presented make a contribution towards assessing where the places with the greatest potential for development are, and what their potential is, using digital representation to compute emerging classifications.

6.1 Clustering of urban blocks

The classification of neighborhoods has been used to evaluate the efficiency of urban design policies (Song and Knaap 2007). Song and Knaap aggregate a set of measures into 8 factors that serve as inputs for k-means clustering. Cluster analysis is used in order to produce classifications of urban form (Gil, Beirão et al. 2012). Other authors characterize urban structure by using data training and discriminant analysis algorithms to produce classifications based on the shape and configuration of buildings (Steiniger, Lange et al. 2008). The most complete and automated computational classification of urban structure taking into account building footprints and block shapes deals with Barcelona (Colaninno, Cladera et al. 2011). The authors are training the model by using established historical periodization: old town, enlargement, 20th century city, fragmented city, city of the seventies, suburb, industrial/commercial/Special Buildings. They subsequently also integrate the structure of the street network into the analysis. A thorough review of pattern classification methods by Duda and Hart (1996), suggests that k-means clustering tends to divide a set of objects into homogeneous groups with no preconceived information about the group structure of the data.

The k-means clustering organizes blocks into clusters that share common properties. The goal is to create clusters that show statistical and numerical evidence of similar patterns/trends (Steadman, Bruhns et al. 2000). With k-means clustering the data are partitioned into a number *k* of clusters, determined by the user.

6.1.1 Classification of blocks by morphological properties

For the purpose of creating a city profile, three morphological factors are selected to characterize the size (area) and the shape of blocks (square compactness and elongation). After several tests, the number of clusters was fixed to 8: fewer clusters did not provide enough discrimination, and more clusters created too many classes with too few elements, and quite small variations of values between clusters.

Table 15. k-means values for 8 clusters that categorize blocks according to area (m^2), square compactness and elongation.

Cluster ID	*n Blocks*	Area *Mean (ha)*	Sq. Cpct *Mean*	Elongation *Mean*		Area *Size*	Sq. Cpct *Boundary*	Elongation *Proportion*
8	*1761*	2.1	0.96	0.75		Small-Medium	Uniform	Square 1:1-2:1
7	*1352*	3.3	0.76	0.63		Medium-Large	Deformed	Elongated 3:1
1	*638*	4.7	0.49	0.5		Large	Interrupted	Narrow 4:1
2	*213*	30	0.39	0.63		Super	Meandering	Elongated 3:1
3	*48*	85	0.31	0.62		Super	Meandering	Elongated 3:1
6	*12*	190	0.23	0.6		Mega	Convoluted	Elongated 3:1
5	*1*	346	0.17	0.51		Mega	Convoluted	Narrow 4:1
4	*1*	503	0.08	0.64		Mega block+	Convoluted	Elongated 2:1

The different clusters are illustrated in Figure 62 and values are reported in Table 15. Regarding the block area, k-means clustering partitions the blocks into groups ranging from small-medium blocks to mega blocks – the blocks larger than one million square meters. Regarding square compactness, which is sensitive to the shape of the block boundary, clusters highlight the range from more regular to convoluted blocks. Finally, regarding elongation, which describes the overall span of the block shape, clusters distinguish between consolidated/compact, elongated and narrow blocks.

This classification of blocks by morphological characteristics provides a first step towards the assessment of an existing state of the urban fabric. Other design characteristics are associated with each cluster. For example in Table 16, the average dimensions of span (longest axis), depth and width are given as well as the average number of block-faces.

Table 16. Mean length by clusters for longest axis, girth, radial depth, and width (average length) and mean number of block-faces

Clusters	n Blocks	Longest Axis	Depth	Girth	Width	n Block-faces
		meters	*meters*	*meters*	*meters*	
4	1	3949	135	532	362	119
5	1	4107	147	428	362	66
6	12	2659	113	382	319	46
3	48	1706	83	265	256	32.5
2	213	982	52	158	228	18.9
1	638	443	20	54	160	6.7
7	1352	296	22	57	130	4.8
8	1761	200	21	57	103	4.1

Exceptional mega blocks

Clusters 4 and **5** pick up extreme and rare blocks with area over 3 million square meters (750 acres). Their longest span is 4 kilometers long (3,000’), with an average width of 362 meters (1,056’) for 120 and 66 block-faces.

Irregular mega blocks

Cluster 6 is made of blocks with a footprint larger than a million square meters (250 acres). Blocks span 2.7 kilometers on average (8,720’) with an average width of 320 meters for about 46 block-faces. **Cluster 3** has similar values as cluster 6, the blocks approximate 85 hectares (210 acres) with a maximum span of 1.7 kilometers (5600’). The width of blocks is 260 meters (840’) on average for a mean of 32 block-faces. Blocks in these clusters are still very irregular mega-blocks.

Super suburban blocks

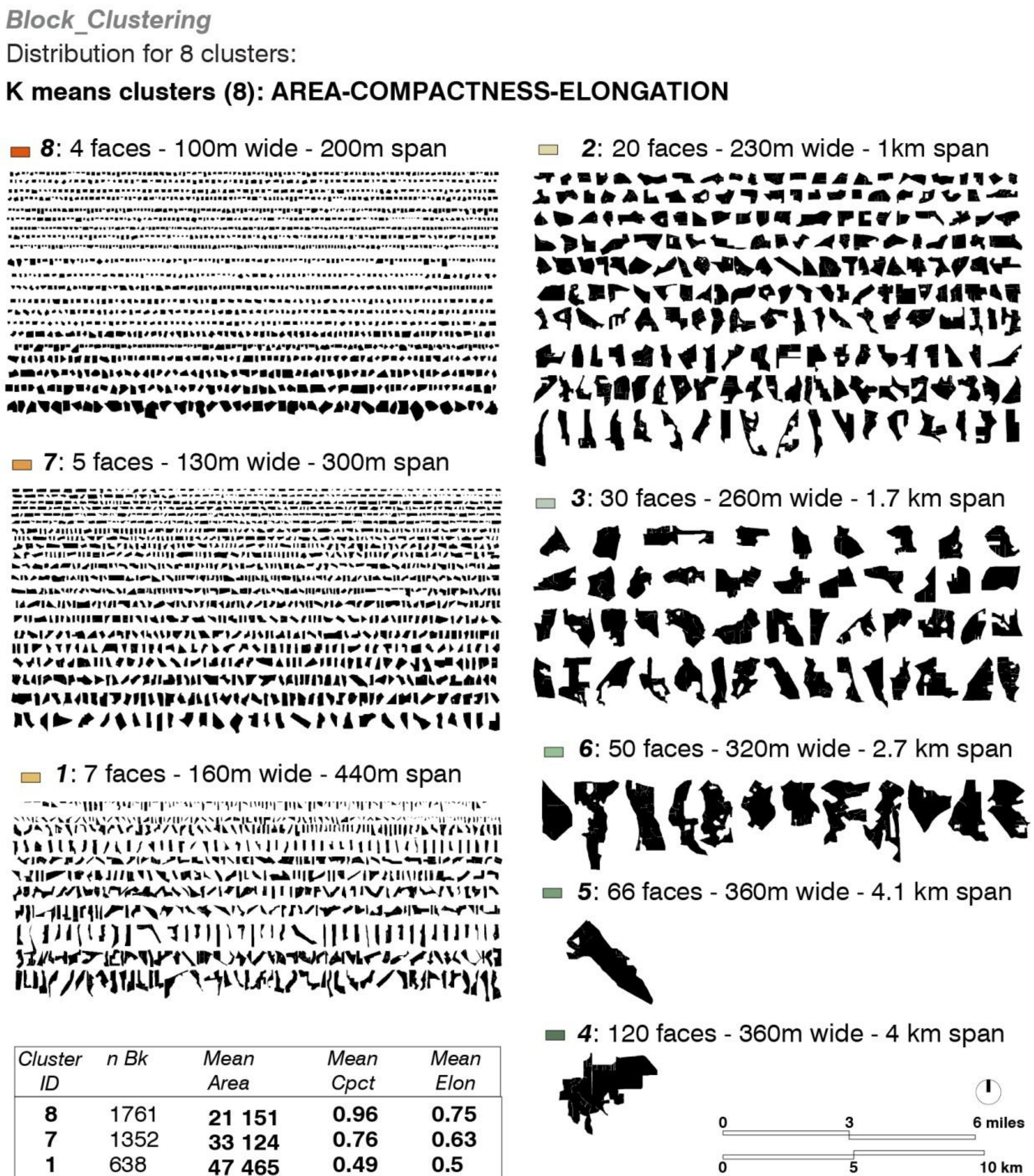
Cluster 2 groups blocks that are too large to be thought of as truly urban, with a mean are of 30 hectares. These blocks are close to the size of the superquadra in Brasilia, which belong to the superblock category. However the difference is that in Brasilia the superblock is a 720 meters (2360’) wide square while in this cluster, blocks are 228 meters wide on average for a mean of 19 block-faces. Their maximum span is almost a kilometer long on average.

Large urban blocks

Cluster 1 is made of blocks with a reasonable mean number of 6.7 block-faces. Their maximum span of 440 meters (1,450’) and a mean width of 160 meters (524’). Their mean area is 4.7 hectares. These dimensions characterize blocks that are quite large but belong to an urbanized section of the city.

Regular blocks

Cluster 7 and **cluster 8** have blocks with an average of 4.8 and 4.1 block-faces that approximate square or rectangular shapes. Their maximum span is respectively 300 and 200 meters (980’ and 660’) with an average width of 130 and 100 meters (430’ and 330’). Their mean size remains fairly large with 3.3 and 2.1 hectares.



Cluster ID	n Bk	Mean Area	Mean Cpct	Mean Elon
8	1761	**21 151**	**0.96**	**0.75**
7	1352	**33 124**	**0.76**	**0.63**
1	638	**47 465**	**0.49**	**0.5**
2	213	**296 370**	**0.39**	**0.63**
3	48	**849 208**	**0.31**	**0.62**
6	12	**1 901 357**	**0.23**	**0.6**
5	1	**3 455 734**	**0.17**	**0.51**
4	1	**5 034 110**	**0.08**	**0.64**

Figure 62. 8 clusters from the k-mean method based on area, square compactness and elongation: table with mean values. For each cluster, the mean number of block-faces, average length (width) and longest axis (span) are reported in meters.

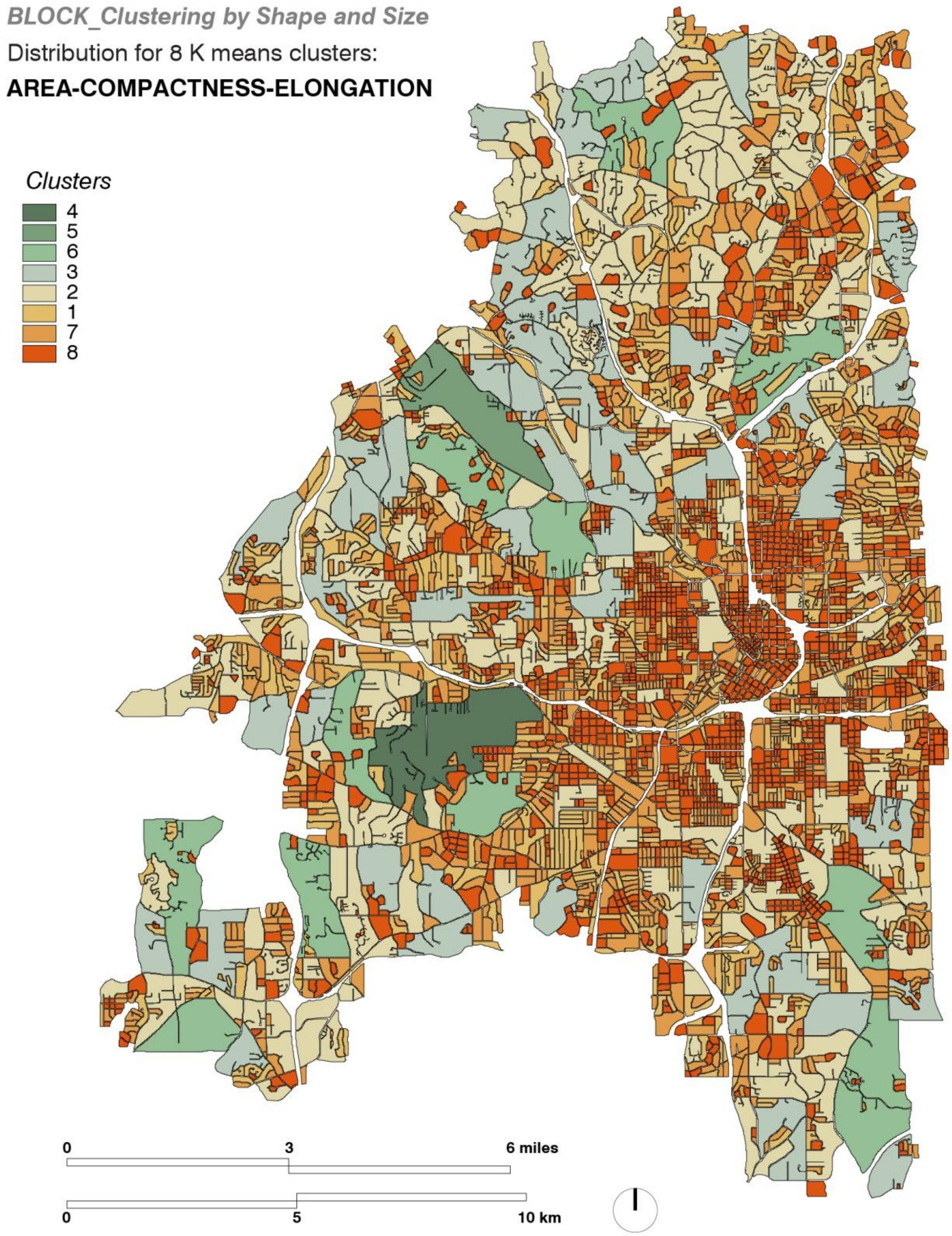


Figure 63. Map of blocks colored by clusters defined by area, compactness and elongation.

Only 824 blocks, 72 blocks of cluster 7 and 752 blocks of cluster 8, are fairly regular and of medium size. Regularity is evident by perusing Figure 38 and Figure 43. In addition to these evidently regular blocks, however, clusters 7 and 8 contain some less regular or less compact ones (Figure 62). The location of the most representative regular blocks is fairly central and in small patches. Thus, a careful examination of the atlas reinforces the statement that large or irregular blocks also cannot be discounted, and tend to create discontinuity of the urban fabric even in areas where small regular blocks are more numerous. The city as whole is definitely not homogenous. Fulton County within the city limits of Atlanta has a great diversity of block sizes, as well as block shapes. And they are all arranged in a non-homogeneous layout.

The presence of very large blocks, on top of disrupting the urban continuity, isolates patches of small and regular blocks that tend to produce a higher ratio of buildings while also increasing the amount of street area

6.1.2 Classification of blocks by street load

For the purpose of understanding the different types of external loads, urban blocks are clustered based on three descriptors. The clustering method by k-means divides the sample into 8 clusters according to the external load measures: local connectivity, measured by metric reach radius 0.17 mile; global connectivity, measured by metric reach radius 5 miles; the regularity of the grid, measured by the directional reach value for 0 direction changes; the regularity of the grid, measured by the number of block faces - this is sensitive to the number of internally and externally oriented T-junctions along the block periphery. The results are reported in

Table 17 that gives the mean values by cluster for each measure and the number of blocks within each cluster.

Table 17. Mean values for 8 clusters based on local [MR0.17], global [MR5] and directional reach with 0 direction change [DR0dc] and the number of block-faces [nBF] that account for the external load of the block. The right part of the table qualify the means according to High [H], Medium [M], or Low [L] values overall.

Cluster	n	MR5	MR0.17	DR0dc	nBF		MR5	MR0.17	DR0dc	nBF
1	*797*	901	1.48	0.51	4.6		H+	H+	M	M-
7	*551*	858	1.05	1.12	5.5		H+	H	H+	M-
8	*1301*	813	0.91	0.36	5.3		H	M	M-	M-
5	*61*	706	0.8	2.48	7		M	M-	H+	M
3	*197*	631	0.66	0.41	24.4		M-	L+	M	H
4	*35*	602	0.61	0.33	59.3		L+	L+	M-	H
6	*1083*	542	0.69	0.26	5.1		L	M-	M-	M-
2	*3*	528	0.73	0.14	139.7		L+	M-	L+	H+

A high mean in directional reach for a cluster represents blocks attached to a major straight and long axis (**cluster 7 and 5**). The highest number of faces is associated with blocks with the lowest global mean reach and directional reach (**cluster 2**). Homogeneous and compact neighborhoods are distinguished by their location: the further away from the center, the lower the metric reach (depicted by **clusters 1, 8 and, 6**). A high number of block-faces is associated with large blocks with normal-medium global and local reach and directional reach (**clusters 3 and 4**).

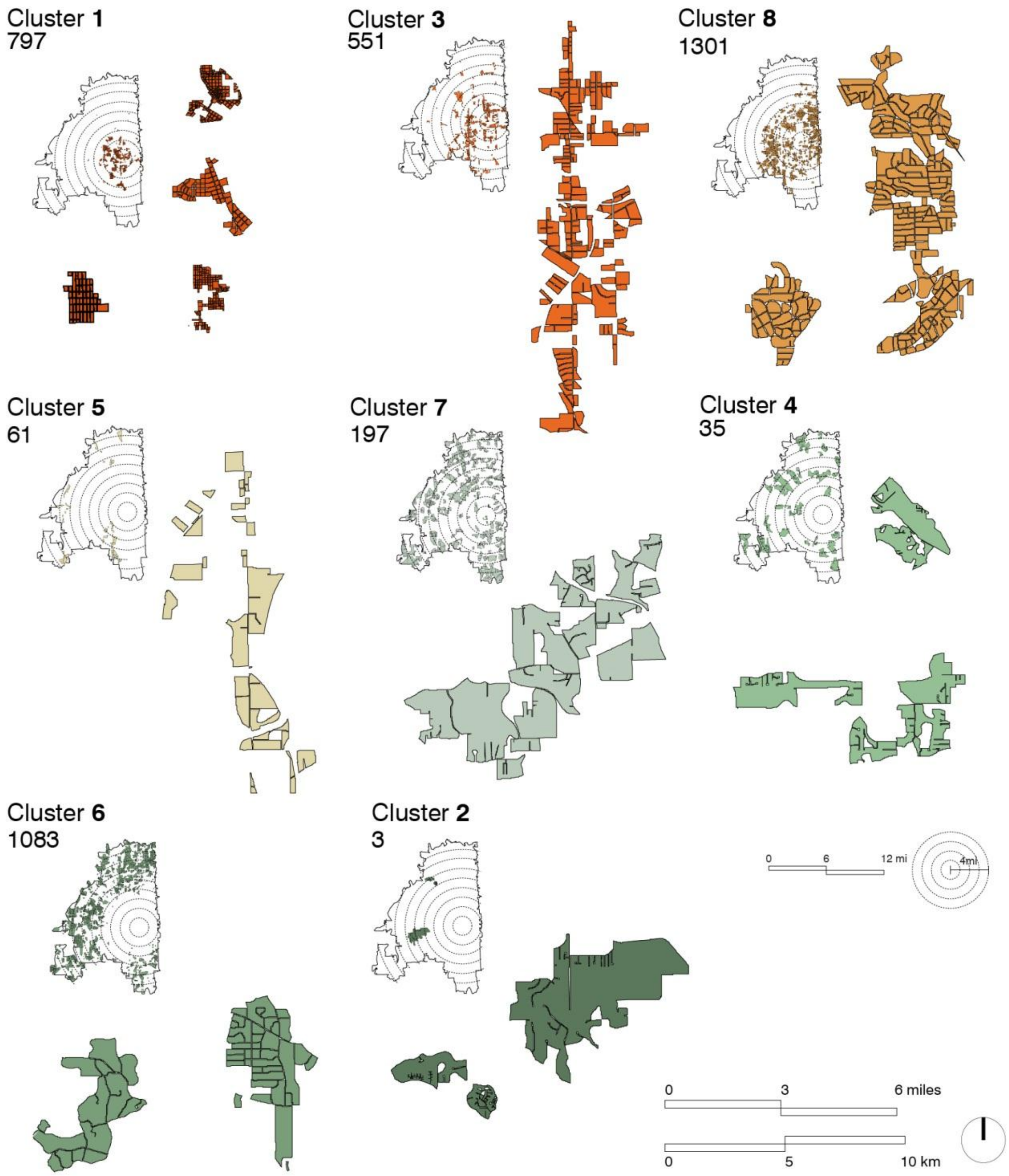
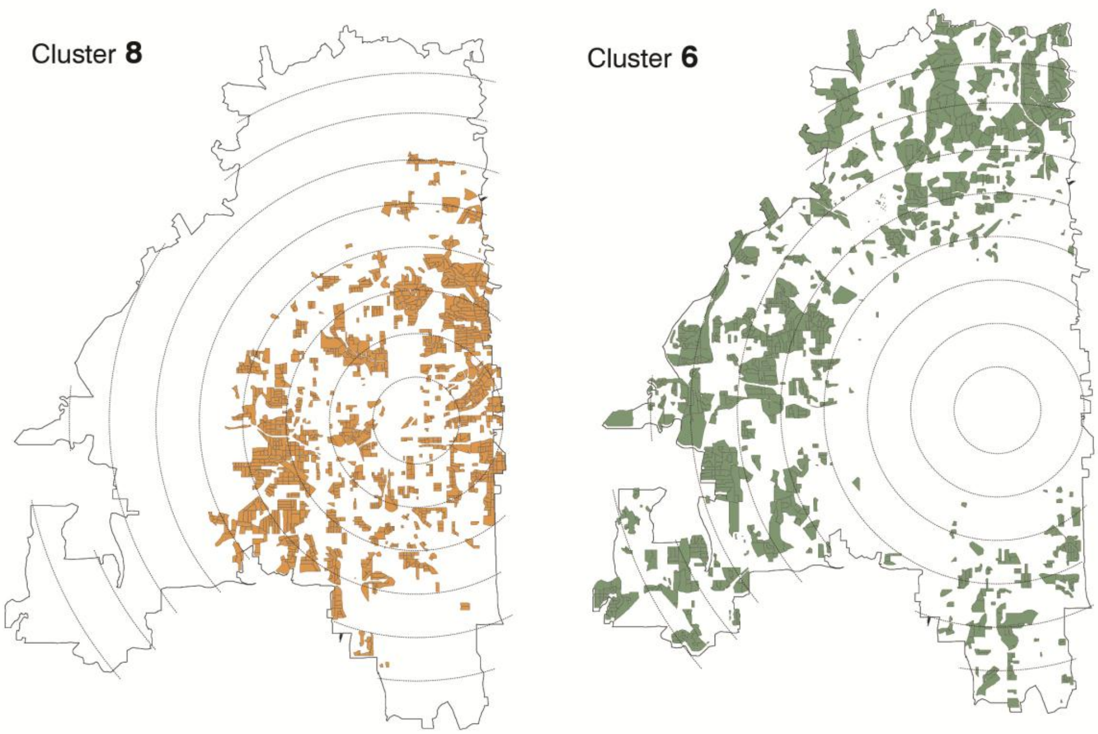


Figure 64. Clusters based on external load which depict configurations and associations in context according to distance from the center, the compactness, the linearity of their association, or their isolation, as well as the complexity of their boundary. The number of blocks is reported for each cluster.

Figure 64 illustrates the different clusters and their location on the map. **Cluster 1** is centrally located and captures small compact neighborhoods made of regular blocks, such as those found, for example, in "*Downtown Atlanta*". **Cluster 7** captures neighborhoods around a major axis ('*North Avenue*'; '*Sylvan Road-Joseph Lowery Blvd.*'). **Cluster 8** captures compact neighborhoods with a more organic structure ('*Ansley Park* for example, with its curvilinear streets based on Olmsted-type principles). **Cluster 6** captures fairly compact neighborhoods at the periphery of the sample. **Cluster 3** captures a few but very large blocks. **Cluster 4** is made of single or double blocks that are large and complex. **Cluster 2** is made of 3 isolated blocks that are very complex (medium, large and extra-large). The most recurrent types of blocks are formed by clusters 8 located within 4-5 miles from the city center and cluster 6 located further away (Figure 65). The second most numerous cases are clusters 1 and 7. From a connectivity standpoint, Atlanta presents fairly discrete neighborhoods with very few connections between them. This pattern of sparse isolated neighborhoods merits further attention to see what kind of building patterns it is associated with.



	MR 5	MR 0.17	DR 0dc	N_Faces
8	H	M	M-	M-
6	L	M-	M-	M-

Figure 65. Clusters 8 and 6 are representing the most common street load on blocks. Their difference is the global reach due to their location on the map.

6.1.3 Classification of blocks by building load

The blocks are clustered according to their internal load to differentiate block types based on building configurations. Table 18 reports the mean values for 7 k-means clusters that are computed based on: building coverage and fragmentation, building enclosure fragmentation and ratio at 20 meters, as well as setback ratio (enclosure at 30 meters has been excluded). The blocks cluster to form three large clusters which can be categorized as follows: large fragmented empty blocks; efficient blocks; and finally blocks with potential [26] for future development. Other clusters have considerably fewer members.

Table 18. Mean values for 7 clusters based on building coverage [BC] and fragmentation [BFg], setback ratio [SK], frontage fragmentation [F20F] and ratio [E20R] at 20 meters that account for the internal load of the block.

Cluster	n	BC	SK	E20R	BFg	E20F
1	*21*	9.4	47.8	36.2	225.1	187.2
2	*132*	11.2	43.9	30.6	123.9	79.1
3	*4*	9	40.8	28.2	523	326.2
4	*1443*	24.2	39.4	44.9	16.3	15.7
5	*1506*	10.1	62.6	11.1	18.6	6.5
6	*204*	60.6	21.8	63.6	4	7
7	*718*	18	34.5	43.5	45.9	34.5

The large fragmented empty blocks:

Cluster 1 has extremely large blocks with around 200 building footprints, mostly located on the edge of the block. They have a low coverage because the center is empty. The natural or man-made internal boundary (Railroad, golf, Chattahoochee River, landfill...) creates a dead-space or edge that cannot be built; density cannot be increased without radical transformation involving either block fragmentation or the creation of new

[26] Within each category variations might occur. It is controlled by the distances to each mean.

access roads and right of way at the expense of existing properties with buildings on them. Thus, these blocks do not have much potential in their present form. **Cluster 2** is a variation of cluster 1 but without the same efficiency/rigor on the edge and with a little more density in the center. They have a slightly higher coverage and a lower enclosure combined with lower fragmentation which imply larger buildings**.** **Cluster 3** is another variation with higher fragmentation due to the size of the block[27], but the coverage is the lowest of the sample.

Clusters 1, 2 and 3 are following similar trends in low coverage, extremely high fragmentation, deep setbacks and average enclosure. These very large blocks with lots of single footprints at the boundary and an underperforming center seem to be characteristic of Atlanta. They are like the suburban block with single-family houses illustrated in Figure 60.

The most efficient

Cluster 6 has the most desirable values for all categories, high coverage with low fragmentation, high enclosure, low setback ratio, low enclosure fragmentation. Only 204 blocks fall in this category.

[27] There is a limitation when using the number of buildings for fragmentation since it is very dependent on the block size with high correlation (coefficient of determination $r^2=60$).

Blocks with potential

Cluster 4 is made of blocks with a fair amount of coverage, relatively shallow setback, a fairly high enclosure ratio and a low fragmentation of the block surface and enclosure. These blocks are quite common. The blocks tend to have a mix of building sizes. Interestingly, the largest **cluster** (**5**) is made of blocks with low building coverage with few building footprints located towards the center of the block. They have the lowest enclosure ratio, therefore a low enclosure fragmentation. Because of their lack of density, they are blocks with potential: low fragmentation, and low coverage (underperforming). The difference between cluster 4 and 5 is their stage of urbanization. Blocks from cluster 4 are a little more built and are located closer to the center, while blocks in cluster 5 are located at the periphery. One could arguably predict that, in a few years, cluster 5 will achieve the same type of building configurations as cluster 4

Cluster 7 includes blocks with similar properties as cluster 4 but with a much higher building and enclosure fragmentation. This difference in fragmentation distinguishes blocks of similar building presence (surface and enclosure wise) and also with potential – the ones with low fragmentation – from blocks which are less desirable – with high fragmentation.

Figure 66 illustrates the different types on blocks according to their building configurations. It shows a concentration of well performing blocks in the center of the city. Based on the location at varying distances from the center and the type of building configuration on them, block clusters illustrate different stages of urbanization. By implication, they also illustrate varying kinds of potential for increased footprint density.

Cluster 7 encompasses two distinctive categories of blocks: large blocks that are built on their center and the small regular blocks that are built on the edge with lots of small discrete buildings (the suburban type in a regular grid). The high fragmentation in the first case is due to the size of the block, and in the latter case it is linked to the density of small buildings within a fairly small block. The latter is definitely a more efficient configuration. The matter of size and shape and how it affects building configurations requires closer attention.

Figure 66. Clusters based on internal load which depict building configurations: their density, their location at the center or on the edges of the block (with the number of blocks in each cluster). The dotted line highlights blocks more likely to evolve.

6.2 Block-face Behavior: clustering

A block-face as previously defined in Figure 44 is the link between the external characteristics of the road structure and the internal pressure of building load. The combination of all these parameters provides a framework for comparing and classifying block-faces. The k-means method previously used is applied once more. Three parameters for the external load and three parameters for the internal load are included in the calculation. The building load is represented with the amount of frontage at 20 meters from the centerline, its fragmentation as well as the presence of setbacks. The external load encompasses the global metric reach with a 5 miles radius, the local metric reach with a 0.17 mile radius and finally the straightness of the road structure with the directional reach with no change of direction.

Table 19. Averages and ranges of internal building load and external street load per block-face. Frontage fragmentation [F20F] and ratio [E20R] at 20 meters and setback ratio [SK] account for the internal load of the block. Reaches with metric reach 5 miles [MR5] and 0.17 mile [MR0.17], with directional reach 0 direction change [DR0dc] account for the external street load.

		n	MEAN	MEDIAN	HALF	QUARTILES	ALL
BUILDING LOAD	[F20R]	*29570*	26.8	22.8	0-23	0 - 45.9	0 - 141
	[F20F]	*29570*	2.92	2	0-2	0 - 4	0 - 46
	[SK]	*29570*	46.7	41.8	18-50	26.7 - 63.8	0.1 - 100
STREET LOAD	[MR5]	*29570*	736	776	770-960	602 - 879	210 - 980
	[MR0.17]	*29570*	0.92	0.86	0.53-1.02	0.63 - 1.16	0 - 3.08
	[DR0dc]	*29570*	0.5	0.24	0-0.24	0.1 - 0.56	0 - 27.5

In a first round, the k-means method distinguishes three clusters with different road characteristics: cluster 1 which represents most of the sample has average connectivity and straightness, the second cluster has fairly high connectivity and straightness, while the smallest cluster has low connectivity but high straightness. The building configurations associated with each cluster have a similar amount of setbacks with a higher ratio for the straighter and less connected. Three clusters do not provide enough differences for classification. Thus, k-means with 8 clusters is used instead. The division in 8 clusters gives 5 clusters of importance in terms of number of block-faces belonging to these clusters, and 3 clusters that can be treated as exceptions (clusters 3, 5 and 7).

6.2.1 Cluster description

Table 20. The mean values for 8 Clusters of block-faces according to three parameters of building load and three parameters of street load. Frontage fragmentation [F20F] and ratio [F20R] at 20 meters and setback ratio [SK] account for the building load. Reaches with metric reach 5 miles [MR5] and 0.17 mile [MR0.17], with directional reach 0 direction change [DR0dc] account for the street load.

	STREET LOAD			BUIDLING LOAD			
Cluster	MR 5	MR0.17	DR0dc	SK	F20R	F20F	n
1	479	0.45	26.42	**92.9**	**0.00**	**0.00**	4
3	53	0.50	12.28	**77.1**	**1.70**	**0.23**	22
2	**543**	**0.64**	**0.29**	80.9	15.15	1.72	4373
4	**588**	**0.70**	**0.24**	31.6	41.87	4.10	7127
6	**867**	**1.12**	**0.46**	74.9	20.26	1.45	5269
7	**869**	**1.19**	**0.48**	25.6	70.86	4.26	8473
8	811	0.99	**3.11**	46.7	34.37	2.49	1296
5	728	0.67	0.28	30.7	67.55	13.56	3006

Several clusters have similar street loads parameters and very different building load and vice versa. Table 20 pairs the clusters with similar characteristics of either building or street loads: clusters 1 and 3, clusters 2 and 4, clusters 6 and 7.

Cluster 1 includes empty block-faces near highways. They have very high directional reach but very low connectivity and are empty. **Cluster 3** is a slight variation of cluster 1 with low building loads. Block-faces have plenty of available space for new buildings but are not connected well to their surroundings.

Cluster 2 includes block faces with almost no building on their edges, but with low setbacks where built. **Cluster 4** includes block-faces that are fairly well built on the edge, with building footprints also covering the interior so that no additional building can easily be added.

Cluster 7 represents the best performing block-faces, they are highly connected locally and globally, they are fairly accessible, the setbacks are minimum (quarter), they are highly built on their edge (70 percent) with a reasonable fragmentation (4 to 5 building footprints on average). They are functioning well. **Cluster 6** has similar behavior for connectivity and accessibility but their building footprint load is very low: only 20 percent of the frontage is built by 1 or 2 building footprints, setbacks indicate lack of buildings with a 75 percent value on average. In the similar location but more empty of footprints, cluster 6 can be seen as containing blocks which are at an earlier stage of development compared to those in cluster 7.

Cluster 8 is average on every level, but with higher values on connectivity and low values on building load with only 35 percent built and fairly low number of building footprints (2 to 3). These block-faces are located near long straight lines that are not highways. They have a very good potential based on their existing connectivity and accessibility.

Cluster 5 seems to represent the suburban type of block-face with lots of building footprints (13.6) and high frontage (68 percent): single-family houses. Block faces in this cluster are fairly well connected globally, but not performing as well locally.

Figure 67. Location of the 8 clusters of block-faces, according to 3 characteristics of building load and 3 characteristics of street load, with circles every 1 mile from City Hall.

Figure 67 illustrates the location of the different clusters at varying distances from city hall. Only the members of clusters 5 and 8 seem to be distributed randomly and regardless of distance from city hall. Cluster 8 is distributed according to the presence of long and straight streets. The distance threshold of 5 miles from center separates clusters 6 and 7 on the inside and 1, 2, 3 and 4 on the outside.

6.2.2 Block-faces in context: homogenous and diverse

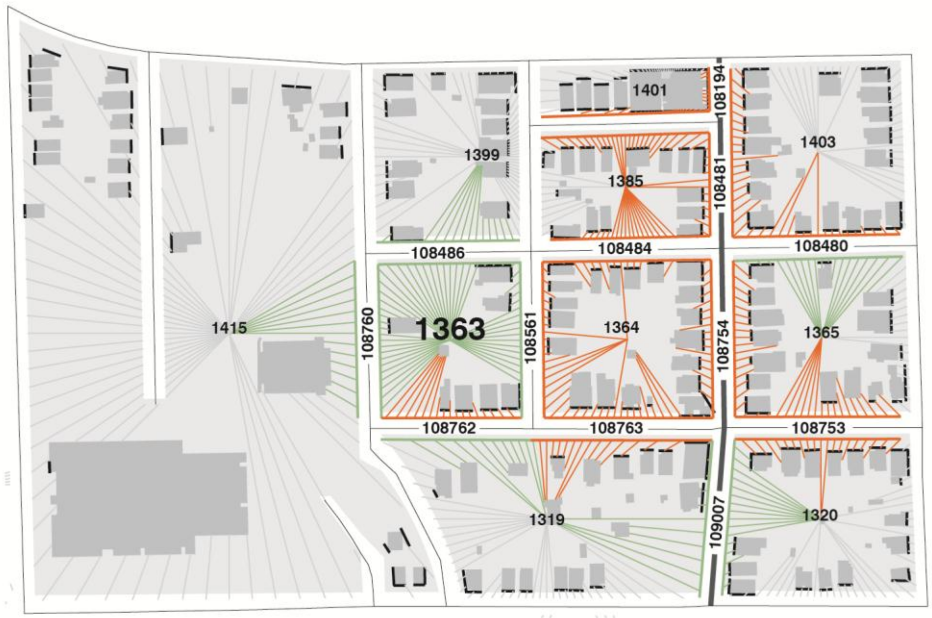
To illustrate the different types of block-faces, examples of streets and blocks are provided in locations with (1) fairly square and compact blocks, and (2) large irregular blocks with diversified conditions on the boundary.

Homogenous context (1)

Block-faces with high local and global connectivity as well as high straightness are associated with two types of building configurations: cluster 7 is made of several building footprints that border half of the block-face with fairly shallow setbacks (one third of the distance to the center); cluster 6 has a configuration made of very few building footprints occupying a tenth of the block front with deep setbacks.

These contradicting configurations of building footprints can either be explained by the non-relationship between the internal load and external load since both building configurations start with a similar street network condition or by considering the building configuration 6 as a stage of development for building configuration 7.

Figure 68 illustrates the difference between clusters 6 and 7 in a fairly regular grid setting made of square blocks near Grant Park. The high value for setbacks in configurations of cluster 6 implies the presence of non-built space between the center of a block and its boundary, which corresponds to available land. They can be qualified as blocks with potential. The configuration represented by cluster 7 is made of numerous discrete buildings that are fairly close to the boundary. This pattern has, to a certain extent, reached its full capacity. The only possibility for expansion is to fill small voids between buildings, creating aggregated configuration, but no large building can be added. This type of block-face is limited in its future prospect but contributes to the continuity of the urban façade.



				STREET LOAD			BUILDING LOAD			
	SgtID	Name	Bk_ID	MR5	MR0.17	DR0dc	SK	F20F	F20R	cluster
STREET: Grant St	108194	Grant St SE	1401	917.1	1.47	1.16	10.7	1	60.7	7
			1403				16.8	3	61.4	7
	108481	Grant St SE	1385	910.0	1.49	1.16	23.9	4	51.4	7
			1403				22.1	5	52.6	7
	108754	Grant St SE	1364	903.4	1.46	1.16	16.7	7	72.4	7
			1365				20.2	7	53.3	7
	109007	Grant St SE	1319	895.9	1.38	1.16	42.9	2	37.8	6
			1320				68.2	4	28.8	6
BLOCK: 1363	108760	Hill St SE	1363	913.9	0.97	0.17	72.9	1	9.1	6
	108486	Orleans St SE	1363	912.2	1.18	0.31	77.4	1	22.1	6
	108761	Broyles St SE	1363	904.9	1.17	0.16	67.1	3	34.0	6
	108762	Milledge Ave SE	1363	905.5	0.97	0.31	36.9	4	39.8	7

Figure 68. Example of configuration 6 and 7 in a regular grid context of Grant park neighborhood.

Diverse Boundary (2)

The example in Figure 69 shows the block that accommodates the Atlanta City Water Works Reservoir 2 with some surroundings blocks. It shows six distinctive types of block-faces. The north side is made of block-faces type 4. They are characterized by low global or local connectivity and medium straightness associated with a fairly small amount of frontage associated to deep setbacks (half way between the center and the boundary) with few building footprints. There is little to be done to improve the existing conditions. In block-face type 8, located on the east side of the block, similar building configurations exist but in a very high connectivity and straightness context. The east side of the block is bordered by Northside drive, which gives lots of potential for buildings that need connectivity and accessibility, but the existing configuration of buildings needs to be improved. The south boundary is fairly unbuilt with block-faces type 3 and is fairly well connected. More buildings could be added. However in that specific example, half of the southern boundary is bordered by the reservoir. The same condition exists for the block-face type 2 but as a cul-de-sac, it is less accessible and less connected.

The surroundings have some block-faces type 5 and 7 that represent the single-family blocks that are fairly dense in the case of type 7 and less for type 5 (Figure 70). Interestingly the corner house will tend to face the block-faces type 7 rather than the block-face type 5.

Figure 69. Example of different block-face types around a fairly large block (Atlanta City Water Works Reservoir 2) that illustrates clusters 2, 4, 6 and 8. The immediate surroundings include also clusters 5 and 7.

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Figure 70. Example of Deering road NW which different conditions at its edges and intersections. It highlights the relationships of block-face types and the direction that buildings face.

In summary, some of the clusters are context dependent: clusters 2 and 6 are concentrated in specific regions, and cluster 8 is linked to specific streets. On the other hand, different building configurations exist for similar street characteristics. The example of the large block (Figure 69) showed that a single block can have variations on its edges to accommodate different building configurations.

The following chapter is looking at the ability of some blocks to create different conditions along their edge. The unit is not anymore the street segment with its two block-faces but the block with its faces. The aim will be to show that a block depending on its shape, size and context can accommodate different types of building configuration.

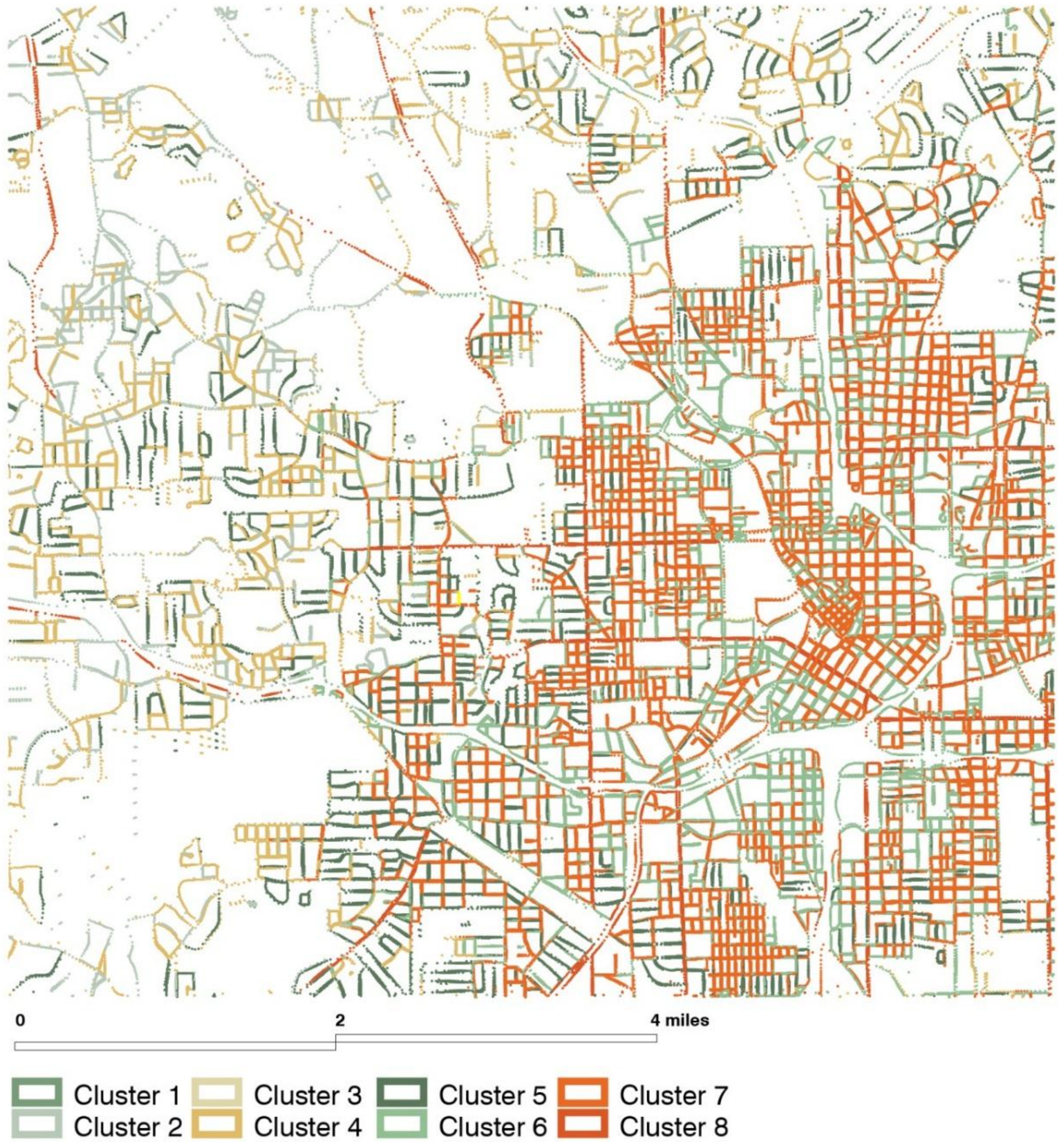


Figure 71. Partial map of the city of Atlanta showing the 8 block-face clusters repartition. The block-faces are represented by points located at the intersection of the block boundary and the radials.

CHAPTER 7

DIVERSIFIED BOUNDARY

Block-face based measures open new possibilities to study relationships between street layout and building configurations. The previous chapter concludes with a discussion on the different types of block-faces along a street – Grant street and Deering road – or along a block boundary – Atlanta City Water Works Reservoir 2 – that display differences of urban conditions. Chapter 5 introduced measures of building load, such as frontage and setback, and measures of streets load, such as metric and directional reach. Because the measures of building and street loads are not averaged by block but disaggregated by block-face, it is possible to measure the effect a diversified block boundary on the surrounding blocks or streets. For example, a diversified block boundary affords a possible distinction between "front" and "back", major and minor, more and less exposed fronts that will be based on differences of connectivity, hence allowing preferable configuration of buildings to match the block-face characteristics.

Evaluating the diversity of block-face conditions is a way to assess the characteristics of the existing street layout for the benefit of future developments. Measures of diversity of building configurations towards the edge of the block provide an account of the existing building stock. The relationship between the building load diversity and the street load diversity is further investigated through correlations. The results show that blocks which have more diversified faces from the point of view of street connectivity exhibit greater diversity of building configurations at the block boundary but reduced overall densities of building frontage.

The shape and size of blocks are then considered for their impact on the diversity of perimeter conditions regarding both building load and street load. Irregular and large blocks have the most differentiated edges. This is because their block-faces are generally of two kinds, outward facing peripheral and internally extended access cul-de-sacs. These two kinds of faces generate very different levels of connectivity and building configurations. Findings as such will need further work to fully comprehend the relationships between internal and external block-faces and building configurations. Initial explorations of the possibilities given by the disaggregation of morphological measures by block-face illustrate the potential of this morphological unit.

7.1 Differentiations: type and method

A previous chapter has described a way to link building load and street load to block-faces. By assigning load value to block-face, it is now possible to assess the propensity of blocks to have different types of faces (Figure 72-a). The boundary differentiation is important when it comes to design blocks that accommodate different types of building configurations. Second, street segments represent the faces of two different blocks, one on each side of the street. Consequently, a block can be linked to the surrounding blocks and be compared to its urban context (Figure 72-b). Differences of values between the surrounding blocks determine if the block is located in a homogeneous or heterogeneous context. The measures of context differentiation matter because they allow us to control the impact of the size and shape of blocks on the syntactic structure of the neighborhood.

Differentiation: coefficient of Variation

[def.]. Boundary and context differentiations are given by the Coefficient of Variation. For a set of data, the coefficient of variation is the ratio between their standard deviation σ and their mean value μ. Sometimes this ratio is expressed as a percentage, also known as Relative Standard Deviation (RSD), or "coefficient of variation". In this paper, the coefficient of variation [CV] is expressed in its percentage form. CV is preferred over standard deviation because of its autonomy from the unit of the data set. As a dimensionless number it can be thus compared with other CV of data sets with different units. It is a normalized measure of dispersion. Small values indicates small amount of variation for the data set and high coefficients relate to more dispersed values.

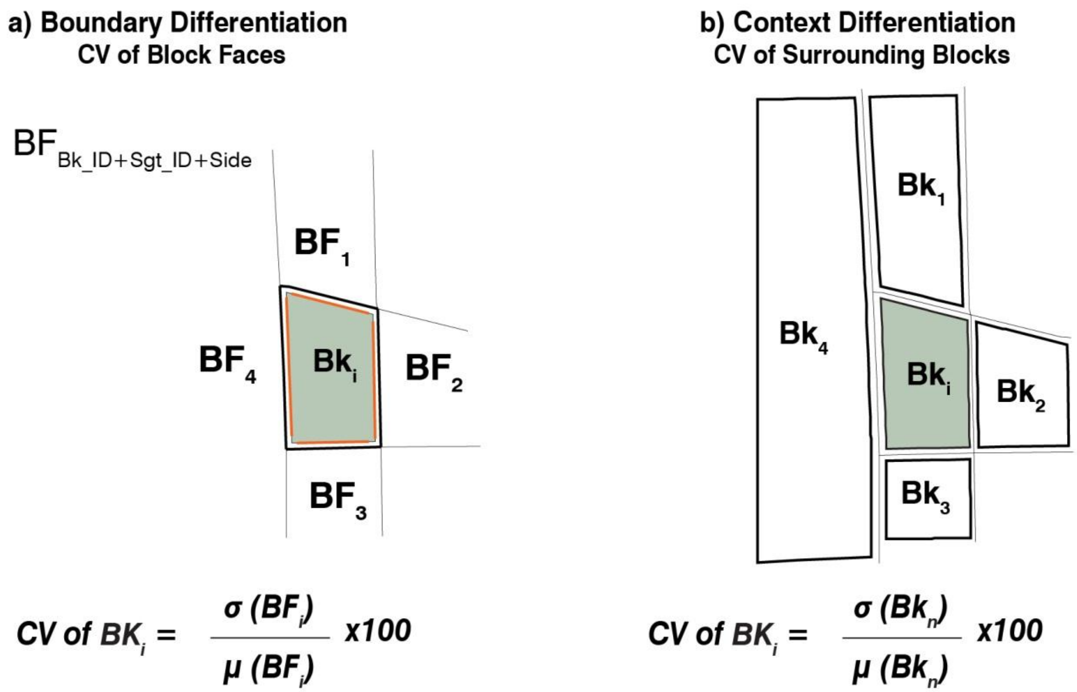


Figure 72. Types of differentiation per block: (a) boundary differentiation, and (b) context differentiation.

When applied to the unit of the block, its calculation varies. For the boundary differentiation, a block *i* is associated to *n* block-faces; the coefficient of variation is computed with the block-face values. In case of context differentiation for a given block *i*, the coefficient of variation is the standard deviation of the values associated to blocks that share a road segment with it divided by their total mean value multiplied by a hundred. The focus of this chapter is primarily on boundary differentiation.

7.2 Boundary Differentiations: a diversified block

The measures of boundary differentiation are aimed at underscoring the diversity of conditions that are provided by the street layout and understanding whether they correlate with diversity of building configurations. The measures that disclose the variations along the block boundary from both the street load and the building load point of view are presented first. Variations between block-faces are measured by the coefficient of variation. Then the impact of number of block-faces on the resulting variations is tested. Finally the comparison between the mean value of street load and building load per block with the coefficient of variations shows that high mean metric reach per block is associated with greater building frontage measured as the mean percentage block-faces that are built. Also, blocks with more diversified metric reach along their perimeter have lesser building frontage. Finally, blocks with more diversified metric reach along their perimeter have more diversified building frontage percentages along their various faces.

7.2.1 Building and street load variations (coefficient of variation)

Coefficient of Variation for Reach per block

[def.] The differentiation by road characteristics is computed according to metric reach radius 5 miles and radius 0.17, to capture global and local connectivity respectively. The last characteristic computed is the difference in zero turn directional reach to measure the difference in the straightness of the road structure.

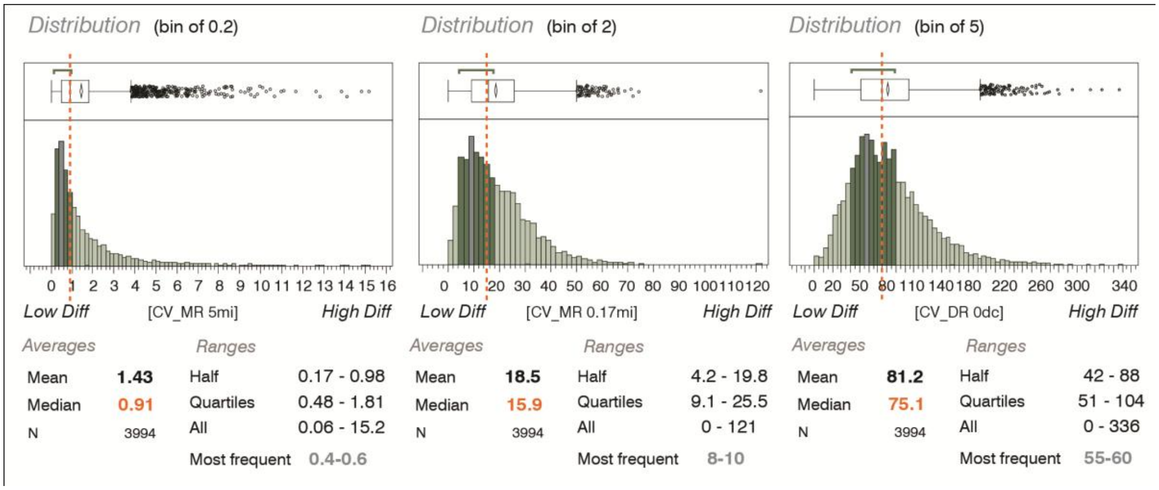


Figure 73. Coefficient of variation for street characteristics per block: metric reach radius 5 miles and 0.17 mile, and directional reach without turn.

The distributions of CV reach show that blocks in general have a low differentiation. The histogram distributions serve as point of reference to determine the levels of differentiation present. Figure 73 shows that the ranges of variation are different for the three measures of street characteristics. Straightness and local connectivity vary the most while there is little variation in global connectivity. The small variation of global connectivity is explained by the overall structure of the city that homogenizes local differences. Variations of local connectivity are lower than expected but significantly higher than global variations. Variations in straightness are the most significant and characterize a street layout that is quite irregular. In the city of Atlanta where the street layout is evenly irregular, blocks have in average an even global connectivity, a quite significant variation of connectivity locally, and strong variations in straightness for their sides. Such conditions might partially cause a type of building configurations depending on the level of connectivity and accessibility.

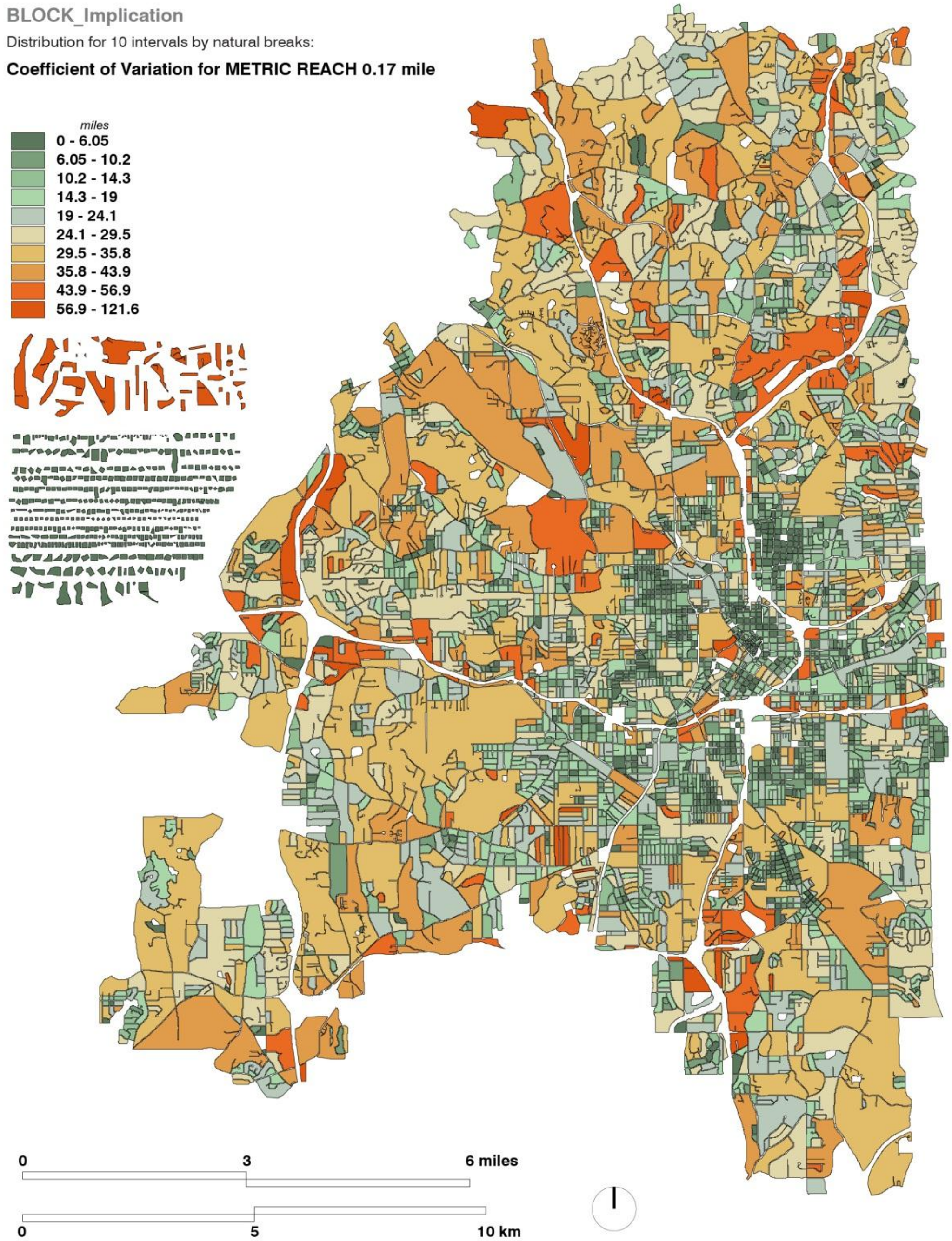


Figure 74. Map of the coefficient of variation for metric reach radius 0.17 mile by block.

Coefficient of Variation for Building load per block

The second set of variations concerns the building load represented by the coefficient of variation for the depth of setbacks, the number of building footprints and the amount of frontage within 20 meters from the street centerline. Figure 75 documents the variations in building configurations along the boundary of the block.

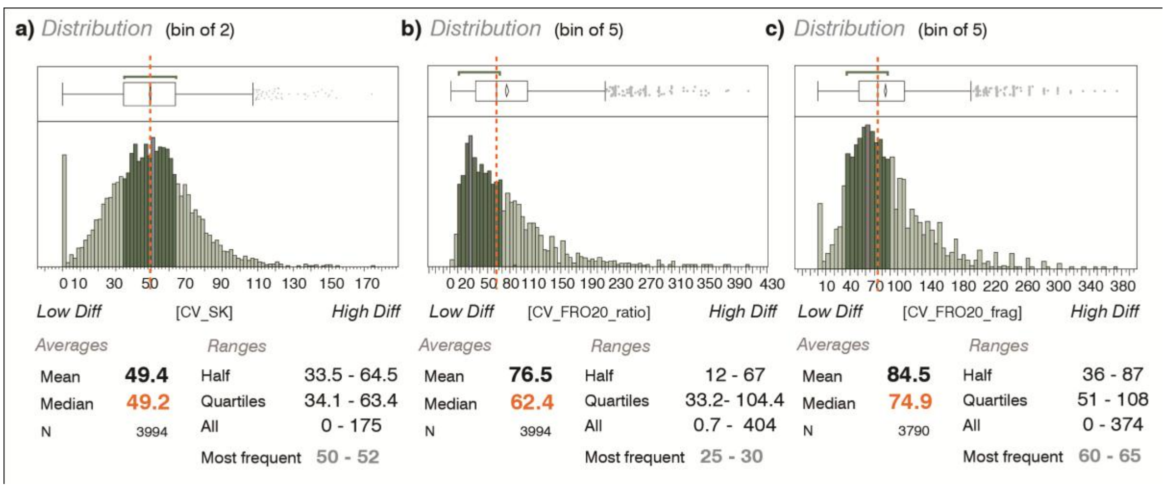


Figure 75. Coefficient of variation for building load by block: a) setback ratio [CV_SK], b) frontage ratio at 20 meters [CV_F20R] and c) its fragmentation [CV_F20F] (averages and ranges).

From the building load point of view, the variations are greater in frontage for both the ratio and the number of fronts than for the amount of setbacks. Setbacks differentiation is inexistent for a large amount of blocks, namely the unbuilt ones. High differentiations in setbacks describe blocks that have their boundary partially and unevenly built as illustrated in Figure 76.

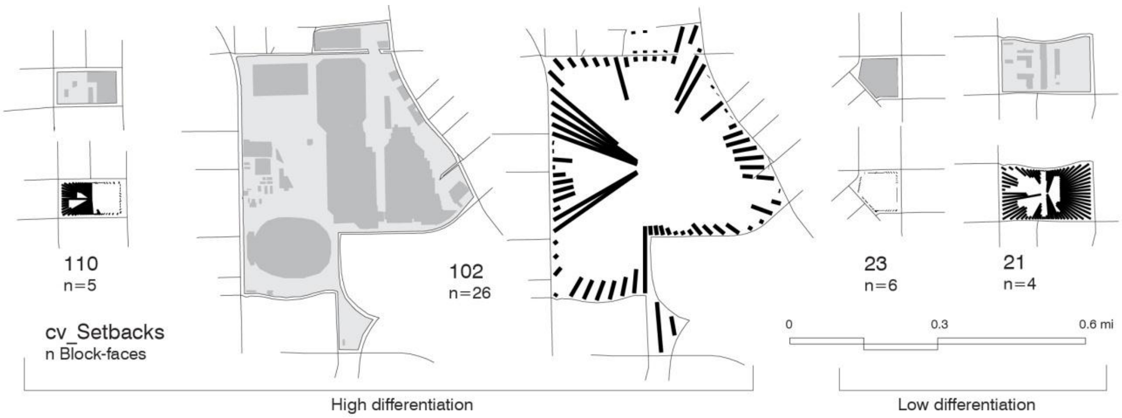


Figure 76. Blocks illustrating ranges of CV setbacks from highly differentiating to low differentiation.

Blocks with very high frontage differentiation are empty blocks with one or two very small frontages on one of their sides compared to their size.

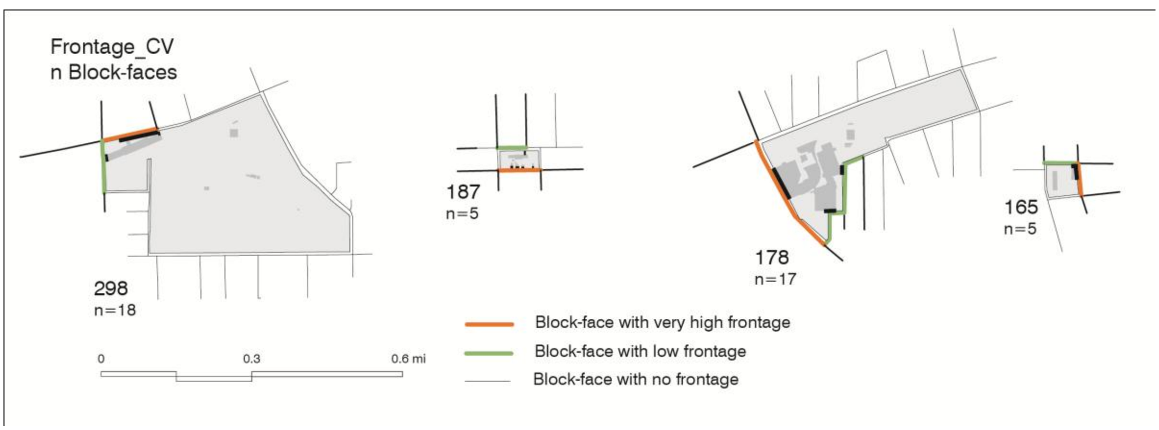


Figure 77. Examples of blocks with very high frontage differentiation within a 20m buffer.

Figure 77 contains examples of blocks with very high frontage differentiation that have a relatively high frontage on one side, low frontage on another and none on the remaining sides. In order to facilitate the intuitive understanding of the numbers, the square small and regular blocks ‘1363’ and ‘1364’ (Figure 68) in Grant park are compared to the large and irregular block '3336' (Figure 69) that accommodates one of Atlanta water reservoirs. Their coefficient of variation in building load and street load are reported in Table 21.

Table 21. Coefficients of variation for building load, with setback ratio [SK], percentage of frontage at 20 meters [F20R], and fragmentation of frontage at 20 meters [F20F]; and for street loads with metric reach 5 miles [MR5], metric reach 0.17 mile [MR0.17] and directional reach no direction change [DR0dc]. Number of block-faces [nBF] is indicated. The 3 blocks selected represent different conditions.

		BUILDING LOAD			STREET LOAD		
		Coefficient of variation					
Bk_ID	nBF	SK	F20P	F20F	MR5	MR0.17	DR0dc
1363	6	56.7	41.8	61.3	0.47	9.5	32.7
1364	5	48.4	21.8	14.4	0.31	9.3	90
3336	16	78.1	143.7	120.7	5.2	27.4	145.4

Variations in reach are more important in the large and irregular block and increase as the radius decreases. The differentiation of straightness is very high in the irregular block compared to the regular ones. The differences of variation are not as strong for the building load. While the CV values for the two square blocks are relatively similar, the CV of the large and irregular block is larger. Can it be inferred that variations are more probable if number of block-faces is larger?

The answer is in the relationship between number of block-faces and building and street loads. Results are reported in Table 22. While all relationships are significant, the only very strong link is between the number of block-faces and global reach. The relationship is weak as far as variations of building load characteristics are concerned.

Table 22. Correlation between the number of block-faces per block [nBF] and the coefficients of variation of building load, with setback ratio [SK], percentage of frontage at 20 meters [F20R]; and the coefficients of variation street load with metric reach 5 miles [MR5], metric reach 0.17 mile [MR0.17] and directional reach no direction change [DR0dc]. Coefficient of determination [r^2], slope with beta value [b] and significance [p] are reported.

		BUILDING LOAD			STREET LOAD		
		Coefficient of variation					
		SK	F20R	F20F	MR5	MR0.17	DR0dc
nBF	r^2	0.07	0.06	0.07	0.30	0.10	0.09
	b	1.06	2.38	2.21	0.20	0.90	2.85
	p	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*

High number of faces are linked to an increase of variations in setbacks (n=4028, b=1.06, r^2=0.07, p<.0001*), amount of frontage (n=4028, b=2.38, r^2=0.06, p<.0001*) and fragmentation (n=4028, b=2.21, r^2= 0.07, p<.0001*). Regarding frontage, a high number of block-faces relates to a decrease the amount of frontage (n=4028, b=-0.54, r^2=0.02, p<.0001*) and the number of buildings footprints (n=4028, b=-0.62, r^2=0.01, p<.0001*). A high number of block-faces increases variability of frontage configurations. Large and irregular blocks will tend to have a more diversified frontage along their different block-faces, but as shown previously very high frontage differentiation is often linked to an absence of frontage on part of the block boundary (see Figure 77).

A high number of block-faces also increases variations in global and local connectivity and direct access. The effect is stronger for global reach (n=3990, b=0.20, r^2=0.30, p<.0001*). Table 10 showed that blocks with a high number of block-faces had lower connectivity. The very high number of block-faces is a proxy for large and irregular blocks, which explains low connectivity overall and the high differentiation of the generally weaker global connectivity values. The large and irregular blocks have very different reach values because of the location of the block-faces inside or on the edges of the block. Blocks-faces located next to the surrounding blocks will have higher connectivity than block-faces lining dead-ends and internal streets. In these cases, the coefficient of variation does not capture the distinction between front and back but rather the distinction between the peripheral and the internal street structure.

The observation merits further attention and could be the basis for future inquiries. Future work will analytically distinguish block-faces lining dead-end and internal streets from block-faces facing surrounding blocks. The location of block-faces inside or at the periphery will also contribute to different building configurations.

7.2.2 **Building and street load relationships** (mean and CV)

This section distinguishes the performances of the block as a whole from the block as made of discrete faces that may perform differently. The two types of performances are represented respectively by the mean value in case of the whole block and the coefficient of variation to capture the differences of each block-face. For example, the mean building frontage represents the ‘enclosure’ of the block, with small values characterizing highly enclosed blocks, while the coefficient of variation assesses the differentiation of the faces by comparing the amount of frontage at each side. Assuming that the street structure comes first, it is necessary to evaluate the impact of the street load, as a whole and as diversified per face, on the overall building load and building diversity.

Overall street characteristics are linked to building load: (mean by mean)

The overall characteristics of street connectivity averaged per block (x axis) have mostly a positive impact on density of building load (y axis) (see Table 13). The amount of frontage is positively correlated to metric reach, but the frontage fragmentation has a negative relationship with connectivity. Directional reach produces no significant relationship. Thus, block-faces with high connectivity are more likely to have a higher amount of frontage and less fragmentation along their frontage.

Table 23. Correlation between mean building load (y axis) – with setback ratio [SK], Frontage ratio [F20R] and fragmentation at 20 meters [F20F] – and mean street load (x axis) – with metric reach 5 miles [MR5], 0.17 mile [MR0.17] and directional reach 0 direction change [DR0dc]. Coefficient of determination [r^2], slope with beta value [b] and significance [p] are reported.

			STREET LOAD								
			Mean								
			MR5			MR0.17			DR0dc		
			r^2	b	p	r^2	b	p	r^2	b	p
BUILDING LOAD	Mean	SK	0.04	-0.02	<.0001*	0.008	-5.27	<.0001*	0.001	-1.71	0.0188*
		F20R	0.18	0.05	<.0001*	0.18	23.5	<.0001*	0.0005	1.05	0.1403
		F20F	0.006	0.00	<.0001*	0.005	-0.5	<.0001*	0.003	-0.29	0.0014*
		F30R	0.13	0.05	<.0001*	0.12	24.2	<.0001*	.	.	0.5461
		F30F	0.008	-0.00	<.0001*	0.06	-2.09	<.0001*	0.007	-0.59	<.0001*

Overall, observations made for individual block-faces match the observations previously made at level of the block. The link of frontage at 20 meters with metric reach at radii 1 mile (n=4028, b=0.5, r^2=0.13, p<.0001*) and 0.5 mile (n=4028, b=0.35, r^2=0.15, p<.0001*) is weaker than for radii 5 miles (n=4028, b=0.05, r^2=0.18, p<.0001*) and 0.17 mile (n=4028, b=23.5, r^2=0.18, p<.0001*). This underscores the impact of very local connectivity and also connectivity at the scale of the city, compared to the scale of the neighborhood. Also, blocks with low metric reach tend to have deeper setbacks. The next step is to look at how the street loads relate to the diversity of building configurations at the block boundary.

Diversity in building load is related to overall street characteristics: (CV to mean)

The linear correlations between the mean value of street loads (x axis) and the CV of the building load (y axis) are reported in Table 24. This shows that increases of connectivity are likely to produce less diversity of building configurations per block-face. While connectivity has a positive relationship with the overall amount of frontage, it has a negative relationship with its diversification. The building configurations are more homogeneous and consolidated.

Table 24. Correlation between coefficient of variations of building load (y axis) – with setback ratio [SK], Frontage ratio [F20R] and fragmentation at 20 meters [F20F] – and mean street load (x axis) – with metric reach 5 miles [MR5], 0.17 mile [MR0.17] and directional reach 0 direction change [DR0dc]. Coefficient of determination [r^2], slope with beta value [b] and significance [p] are reported.

			STREET LOAD								
			Mean								
			MR5			MR0.17			DR0dc		
			r^2	b	p	r^2	b	p	r^2	b	p
BUILDING LOAD	CV	SK	0.06	0.03	<.0001*	0.02	0.16	<.0001*	0.01	6.03	<.0001*
		F20R	**0.07**	-0.09	<.0001*	0.08	-47.8	<.0001*	0.004	8.8	<.0001*
		F20F	0.06	-0.07	<.0001*	**0.10**	-45.3	<.0001*	0.008	10.6	<.0001*
		F30R	0.01	-0.02	<.0001*	0.02	-18.4	<.0001*	**0.02**	13.4	<.0001*
		F30F	0.04	-0.04	<.0001*	0.08	31.1	<.0001*	0.01	10.3	<.0001*

The correlation with the diversity of setbacks conditions is however positive. Local connectivity has a stronger relationship with the differentiation of frontage and its fragmentation than global connectivity. Global connectivity has a stronger link with diversity of setbacks. Straightness has a weak but positive and significant link to all building load diversity, while it had a negative relationship with mean fragmentation frontage and setbacks. The changes of sign of the beta value indicate a different role of street layout on building density compared to diversity of building configuration.

Amount of building load is related to diversity of street characteristics (mean to CV)

The set of linear correlations presented in Table 25 tells if the overall amount of buildings and their location is linked to diversity in street load. Variations of street connectivity and straightness of the block-faces have an overall negative relationship with the amount of frontage and its fragmentation. They have a positive relationship with the depth of setbacks: more diversity is linked to overall deeper setbacks.

Table 25. Correlation between mean building load (y axis) – with setback ratio [SK], Frontage ratio [F20R] and fragmentation at 20 meters [F20F] – and coefficient of variations of street load (x axis) – with metric reach 5 miles [MR5], 0.17 mile [MR0.17] and directional reach 0 direction change [DR0dc]. Coefficient of determination [r^2], slope with beta value [b] and significance [p] are reported.

			STREET LOAD								
			CV								
			MR5			MR0.17			DR0dc		
			r^2	b	p	r^2	b	p	r^2	b	p
BUILDING LOAD	Mean	SK	0.01	1.26	<.0001*	0.003	0.09	0.0004*	0.01	0.05	<.0001*
		F20R	**0.10**	-4	<.0001*	**0.09**	-0.48	<.0001*	**0.03**	-0.08	<.0001*
		F20F	0.002	-0.07	0.0035*	0.0005	0.00	0.1504	0.01	-0.01	<.0001*
		F30R	0.08	-4.47	<.0001*	0.07	-0.55	<.0001*	**0.03**	-0.1	<.0001*
		F30F	0.005	0.13	<.0001*	0.02	0.03	<.0001*	0.008	-0.01	<.0001*

The strongest coefficient of determination is for global diversity. More diversity in global connectivity is linked to less frontage and deeper setbacks.

Variety of conditions for building load is related to diversity of street characteristics: (CV to CV)

Higher variations of local and global reach values increase variation of block frontage significantly. Variations of straightness also increase variations of frontage but not as strongly. However, the coefficient of variation per block of setbacks does not correlate significantly with global metric reach differentiation and has a very weak link with local metric reach and directional reach differentiation.

Table 26. Correlation between coefficient of variations of building load (y axis) – with setback ratio [SK], Frontage ratio [F20R] and fragmentation at 20 meters [F20F] – and coefficient of variations of street load (x axis) – with metric reach 5 miles [MR5], 0.17 mile [MR0.17] and directional reach 0 direction change [DR0dc]. Coefficient of determination [r^2], slope with beta value [b] and significance [p] are reported.

			STREET LOAD								
			CV								
			MR5			MR0.17			DR0dc		
			r^2	b	p	r^2	b	p	r^2	b	p
BUILDING LOAD	CV	SK	0.0009	0.44	0.0647	0.005	0.14	<.0001*	0.005	0.03	<.0001*
		F20R	**0.11**	12.14	<.0001*	**0.11**	1.55	<.0001*	**0.05**	0.31	<.0001*
		F20F	**0.11**	11.04	<.0001*	**0.14**	1.56	<.0001*	**0.05**	0.27	<.0001*
		F30R	0.07	6.69	<.0001*	0.08	0.97	<.0001*	0.05	0.22	<.0001*
		F30F	**0.12**	8.47	<.0001*	**0.17**	1.26	<.0001*	**0.06**	0.22	<.0001*

Differences in the straightness of the road structure have small effect upon the diversity in building configurations at the block boundary, and the effect is positive. The diversity of street characteristics has a positive impact on frontage diversity. The link is stronger for the frontage included within a 30 meters buffer than a 20 meters one. In summary, blocks that have more diversified metric reach along their perimeter have more diversified building frontages along their various faces.

7.3 Discussion

The impact of street load on building load by whole blocks or according to the differentiation by block-faces shows evidence that the street layout embeds in its structure differences that drive building locations and building density. The differentiation by block-faces has a strong relationship with the occurrence of frontage and is associated with different types of building configuration. In order to illustrate different types of relationship between the building load and the street structure, some blocks have been selected to exemplify variations within a homogeneous type of shape and size.

Figure 78 illustrates the different frontage loads that are accommodated in rectangular blocks of 400 by 180 feet that have a low local metric reach coefficient of variation. The coefficient of variation ranges from 6.5 for a homogeneously built block, to 187 with a block built a fair amount on one of its sides, only slightly on another and not at all for the remainder. The type of building configuration is principally single-family houses, only the amount varies. In Figure 79, the selected blocks are square measuring around 400 y 400 feet and accommodate different building configurations; their metric reach CV is very low while the blocks are located in a highly connected area.

These last two examples used fairly small and regular blocks that carry different building configurations. It has been also shown that the blocks that are the most differentiating in terms of street loads are blocks with high number of block-faces. The following section is asking what is the influence of shape and size of blocks on both building and street differentiations.

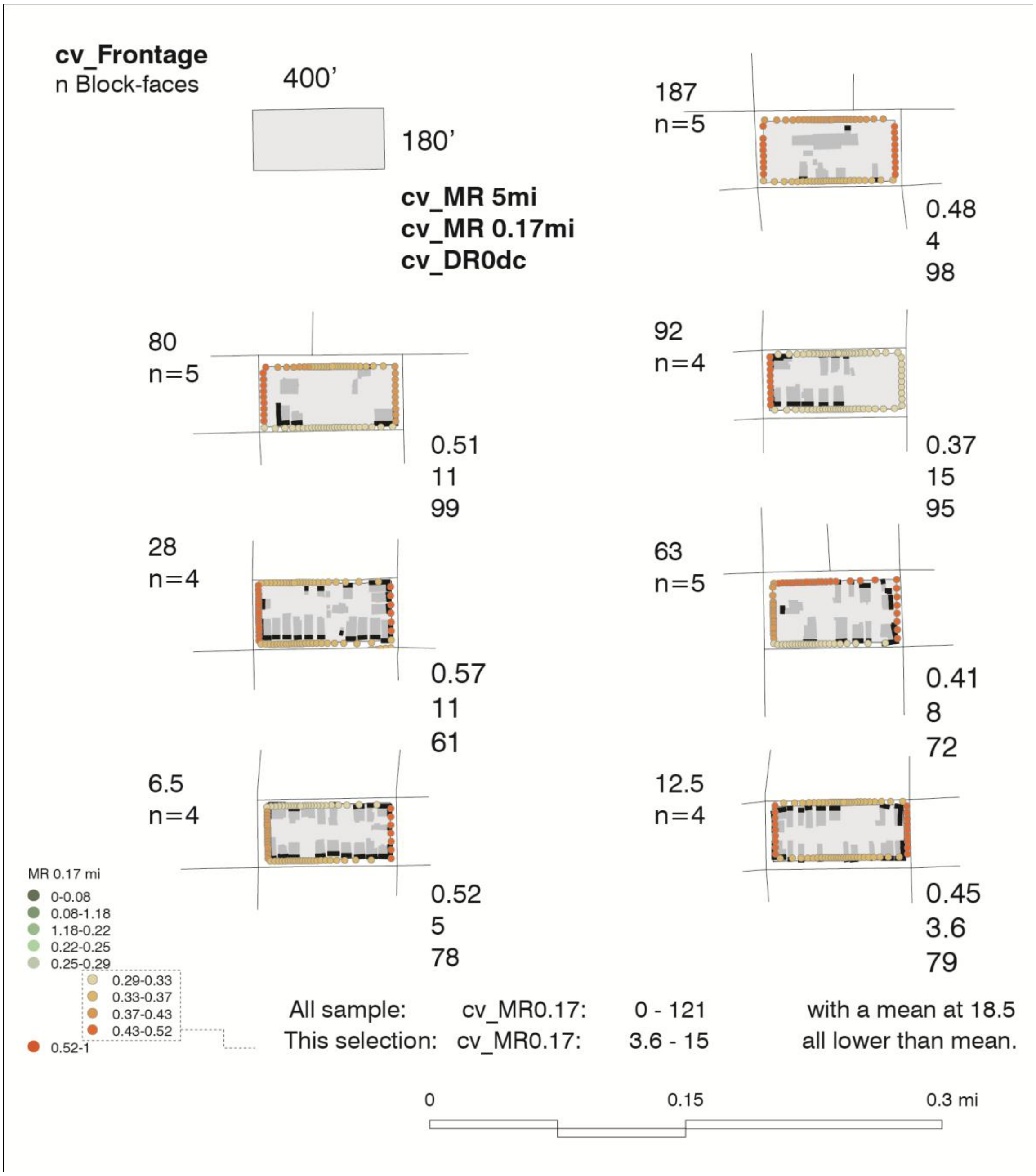


Figure 78. Rectangular blocks 400' by 180' with different building configurations that produce a range of frontage differentiation conditions (20m buffer). Metric reach at 0.17 mile is indicated to show the small variations that occur locally on the street structure. Coefficients of variation for metric reach 5 and 0.17 miles and directional reach 0 direction change are reported.

n=49	MR5mi		Mr0.17		DR0dc		If compared to all sample
	mean	ranges	mean	ranges	mean	ranges	
Mean	929	863-976	1.24	07-1.5	0.71	0.07-1.5	HIGH
CV	0.54	0.09-1.97	11.8	2.4-55.9	68.5	13.9-137.5	LOW

Figure 79. Examples of square blocks 400 by 400' that have different building configurations, with a low coefficient of differentiation and high mean of street loads.

7.4 Context versus individual blocks:

The last question addresses whether the context or the block morphology impact building presence. Does context have a more important role than the shape and size of each individual block?

7.4.1 Shape and size influence on building and road differentiation

The shape and size of blocks are the elements that can be controlled more easily during the design phase. The interest is then on how the shape and size of blocks impact the diversity of building load and street load. Measure of size (log area) and shape (compactness to a square and elongation) of blocks are plotted against the coefficient of variation of setbacks, frontage and frontage fragmentation first; and then against metric reach at 5 and 0.17 miles and directional reach. The results are presented in Table 27.

Table 27. Correlation between size – area logged – shape – compactness to a square [CPCT] and elongation index [ELON] – of block and differentiation of building load – with setback ratio [SK], Frontage ratio [F20R] and fragmentation at 20 meters [F20F] – and street loads – with metric reach 5 miles [MR5], 0.17 mile [MR0.17] and directional reach 0 direction change [DR0dc]. Coefficient of determination [r^2], slope with beta value [b] and significance [p] are reported.

			BUILDING LOAD			STREET LOAD		
			SK	F20R	F20F	MR5	MR0.17	DR0dc
			Coefficient of variation					
SIZE	AREA Log(area)	r^2	0.05	**0.18**	**0.22**	**0.42**	**0.30**	0.08
		b	4.05	20.5	19.7	0.81	5.3	9.2
		p	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
SHAPE	CPCT 0=irregular 1=compact	r^2	0.02	0.07	**0.10**	**0.27**	**0.28**	**0.09**
		S	-11.8	-68.4	-74.6	-3.7	-29.8	-58.4
		b	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
	ELON 0=elongated 1=compact	r^2	-	0.02	0.06	0.07	0.16	0.02
		b	-1.75	-84.4	-115.6	-3.81	-45.5	-60
		p	0.6116	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*

Size has the strongest relationship with differentiation of building and street loads. It has a positive impact while both measures of shape have a negative impact. Increase of size is linked to more differentiation while the more compact and regular blocks are the least differentiating. Elongation does not impact setback differentiation, and it has a weak impact on most other differentiation, excepted on the differentiation of local reach. As blocks are less elongated, less differentiation exists between the local reach values of its faces.

Larger blocks with a deformed boundary are more differentiating. The very large blocks with very meandering boundary differentiate the most. The least differentiating blocks are the regular and compact ones. The differentiation of global connectivity is dependent primarily on size, as well as compactness while elongation has the least effect. Again, the least differentiating blocks are the smaller compact ones; differentiation increases with increases of size and elongation and reduction of compactness.

7.4.2 Building Frontage and Coverage in context

Building densities are captured by building coverage for the whole block and by building frontage for the block boundary. The hypothesis is that the existence of building densities is more a matter of context than a matter of individual block. To test if context matters more than individual blocks, a multiple regression model is built that includes the effect of external load differentiation and the effect of the shape and size of blocks.

The two selected measures of context are local differentiation and global reach. Local differentiation, coefficient of variation of metric reach radius 0.17, is chosen over global differentiation because variations are more visible locally than globally. Global reach is chosen over local reach because density of streets has more impact when it includes a larger context. Metric reach at 5 miles is averaged by block. For measures of block morphology, compactness to a square is not included because of its auto-correlation with area and the elongation index.

Building Coverage ratio in context:

The first model is looking at the impact of context and block morphology on the overall building coverage. The results are reported in Table 28.

Table 28. Multiple regression model, with building coverage [BC] as the y variable and mean metric reach 5 mile [Mean_MR5] and cv metric reach 0.17 [CV_ MR0.17] for context and the size with the logged Area [log_AREA] and Elongation index [ELON] for block size and shape.

Standard Least Square	**Building Coverage [BC]** is the y variable					
R^2	**0.31**					
n	3992					
p	<.0001*					
Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta	VIF
Mean_MR5	0.51	0.02	28.54	<.0001*	**0.48**	1.20
Log_ AREA	-0.87	0.18	-4.84	<.0001*	**-0.08**	1.6
ELON	11.7	1.85	6.3	<.0001*	**0.09**	1.22
CV _MR0.17	-0.03	0.02	-1.55	0.1218	**-0.03**	1.68

The only non-significant measure is the coefficient of variation for metric reach 0.17 mile. Local differentiation does not impact the overall building coverage of the block. The density of the surroundings impacts building coverage the most. The more connected to its context the block is, the more built it becomes. The beta value is 4 times stronger than the one of area and elongation. However, area and elongation both have a significant impact on building coverage. The increase of block size reduces the amount of coverage, and the reduction of elongation increases coverage. Connected, compact and small blocks will have more overall building density. But most of all, the beta value of global density is 6 times larger than all the other measures. The context matters much more than individual block characteristics.

Building Frontage ratio in context:

The first model is looking at the impact of context, shape and size of blocks on the building frontage within a 20 meters buffer. The results are reported in Table 29.

Table 29. Multiple regression model, with building frontage [F20R] as the y variable and mean metric reach 5 miles [mean_MR5] and cv metric reach 0.17 [CV_MR0.17] for context and the logged Area [log_AREA] and Elongation index [ELON] for block size and shape.

Standard Least Square	**Building Frontage [F20R]** is the y variable					
R^2	**0.23**					
n	3992					
p	<.0001*					
terms	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta	VIF
Mean_MR5	0.04	0.00	23.09	<.0001*	**0.35**	1.20
CV_MR0.17	-0.25	0.03	-8.58	<.0001*	**-0.15**	1.67
ELON	10.82	2.79	3.87	0.0001*	**0.06**	1.22
Log_AREA	-0.88	0.27	-3.23	0.0012*	**-0.06**	1.59

All independent variables produce significant effects. The density of the surroundings relates to building frontage the most. The local reach differentiation is more impacting than elongation and area. Higher differentiation has a negative impact on frontage. There is confirmation that large blocks have lower frontage, and less elongated blocks greater frontage. The standard beta values show that the impact of mean metric reach 5 miles is five times higher than that of elongation and the area of blocks, and that the impact of the coefficient of variation of metric reach 0.17 mile is 2.5 times higher than blocks size and shape. Once more, the context matters more than the individual block characteristics, but the variations along the blocks boundary are also important to decide how to build the edge of the block.

The street layout connectivity as an important factor of building density is established for the city of Atlanta. More regression models could be constructed to refine the effect of context on building configuration: the impact on setbacks, or on building fragmentation or frontage fragmentation. This analysis confined itself to building density to exemplify the impact of street layout on building. Now, an exploration of the impact of a block on the characteristics of adjoining blocks is proposed.

7.4.3 Diversified context: Homogeneous or heterogeneous contexts.

After showing that street layout connectivity has an impact on building densities, the focus shifts on the ability of block morphology to influence the immediate context. The question is whether block morphology is linked to characteristics of adjacent blocks. Each block is linked to the set of blocks that share a street to look at homogenous or heterogeneous context.

Impact of size

[def.] The Block Area Differentiation per block is equal to the coefficient of variation of the areas of adjacent blocks; it measures if the area encompassing the block is homogeneous or heterogeneous relative to block size. It places each block into its immediate context, but does not compare its size to the surrounding block sizes (see example in Figure 81-d, where a very large block is surrounded by all very small blocks). Blocks with a high coefficient are located in non-homogeneous areas relative to block size (Figure 81-a-b-c).

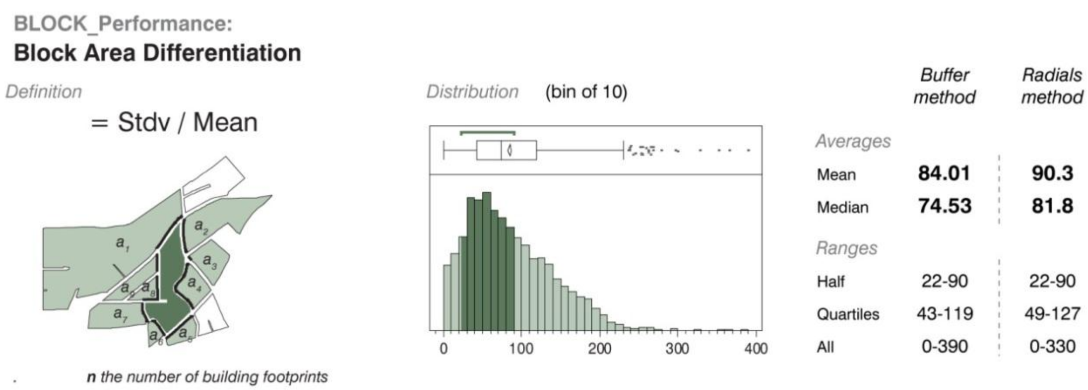


Figure 80. <u>Block area Differentiation</u> definition and distribution (averages and ranges).

Most blocks have a low coefficient of variation; they are located in fairly homogeneous fabric. Because half of the sample is located below the mean value, very few blocks are highly differentiating. High coefficients of variation describe two types of blocks: the very large blocks that are at the intersection of different types of neighborhoods, or the very small blocks on the edge of the large blocks (see example in Figure 81-c in which a very small block (orange) acts as a buffer between a very homogeneous urban grid and a very large block. By comparison, the block next to it (green) is not differentiating at all since it is not in direct contact with the large block.

Figure 81. Examples of Block Area Differentiation: a) high differentiation for a large block, b) high differentiation for a small block, c) two small blocks with high and low differentiation, d) low differentiation for a large block and e) low differentiation for a small block.

Impact of shape

[def.] The Block Compactness Differentiation per block is equal to the coefficient of variation of compactness of adjoining blocks. The coefficient measures whether a block is located in an area of similar or dissimilar block shapes. While the coefficient places each block into its immediate context, it does not compare its shape to the surrounding block shapes (see example c in Figure 83).

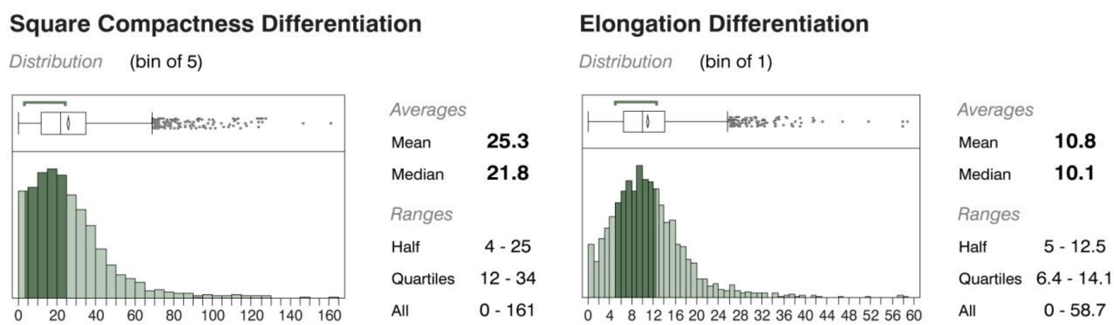


Figure 82. Ranges and Averages values for Block Shape External Differentiation: Square compactness and Elongation

The majority of blocks have low shape differentiation. The histograms in Figure 82 show positive skewness for square compactness and elongation (1.6 and 1.3. respectively). The sample has relatively few blocks that are associated with very high differentiation values. In both cases, the mean value is located near the upper limit of the half range. The highest differentiation is 6.4 times greater than the mean for square compactness differentiation and 5.4 times for elongation differentiation.

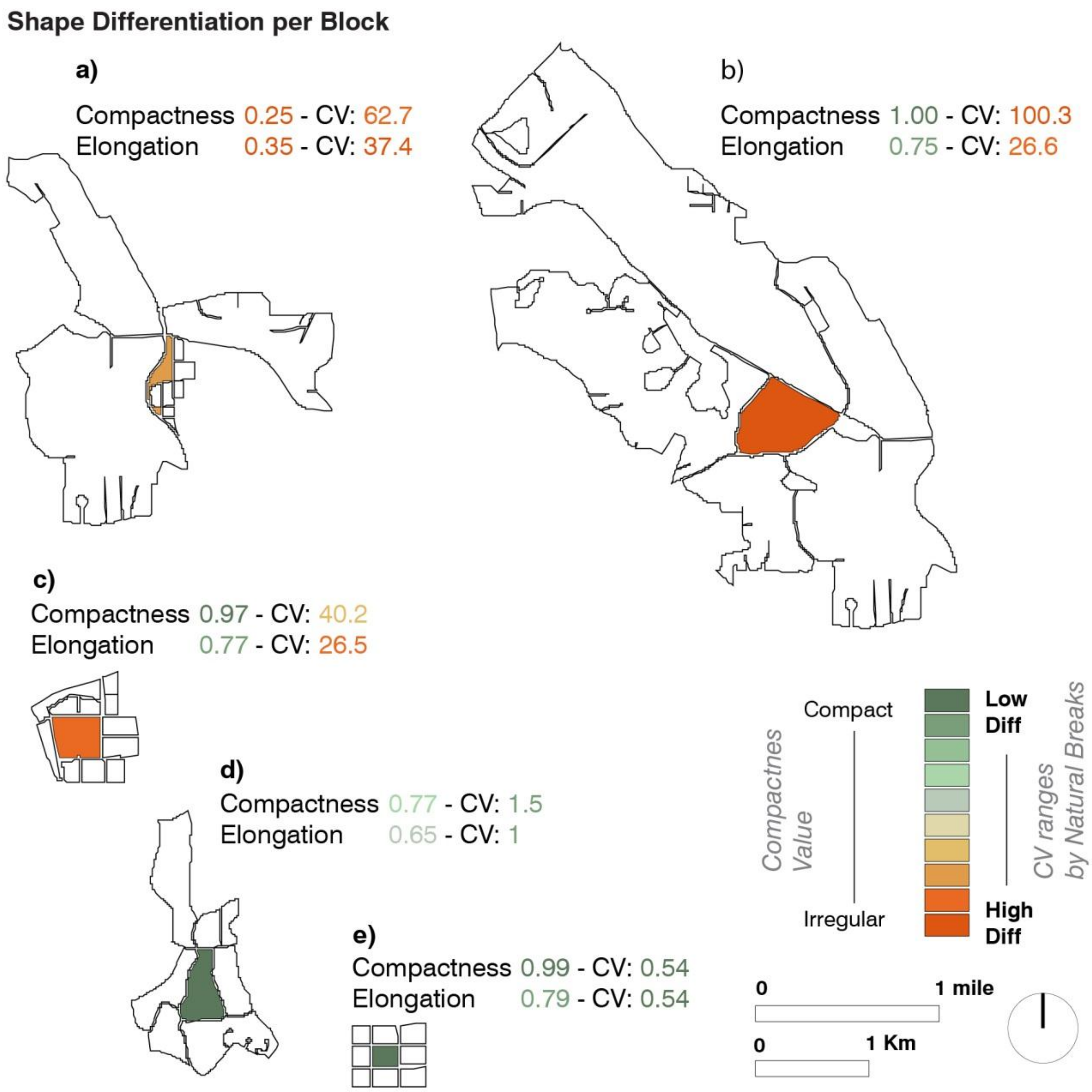


Figure 83. Examples of blocks with different compactness and coefficient of variations values: very irregular and elongated block (a) and very compact block (b) in highly differentiated context; square blocks in highly differentiated context (c) and in homogeneous context (e); and irregular block in homogenous context of irregular blocks (d).

The square compactness of a block correlates negatively with its compactness differentiation (n=3678, b=-18.4, $r^2=0.03$, $p<.0001$*), and elongation of a block correlates also negatively with its elongation differentiation (n=3675, b=-11.3, $r^2=0.02$, $p<.0001$*). Compact blocks tend to be located in homogeneous surroundings, while very complex blocks tend to be surrounded by blocks of various shapes.

Figure 83 illustrates different cases of regular and irregular blocks within homogeneous or highly differentiated contexts. The context of a block that is highly differentiated in elongation has a high differentiated compactness (n=3678, b=0.14, $r^2=0.17$). Irregular and elongated blocks tend to be located in differentiated contexts; regular and compact blocks are usually found in homogeneous contexts.

CHAPTER 8

CONCLUSION

8.1 Findings

The analysis presented in this thesis demonstrates that block-faces are an interface between internal and external forces which systematically act upon one another. The connectivity of the street associated with a block face has been shown to be a significant morphological driver of building configuration, more powerful than individual block shape and size. Thus, syntactic context matters more than block properties. Accordingly, cities have to be thought in terms of dynamic relationships between their elements, from block to street, from block to block and from street to street. These interrelationships provide the basis for answering the question raised in the introduction: How can we maintain and create diversity within urban form to provide a more flexible local structure for development while keeping a cohesive and stable global syntactic structure?

8.1.1 Stable and flexible at once: a claim for diversity

The main criticism of zoning is its propensity to separate functions by assigning land-uses to a definite geographical area. Often, zoning does not explicitly take into account the dynamics of flows and connectivity. The focus is mainly on the accessibility of individual locations. Rather than focus exclusively on the merits of particular locations, cities should be thought of as wholes supported by an overall street network, which provides accessibility and connectivity to their parts. If we think of cities in terms of localized pockets of denser urbanism or in terms of zones, we miss a sense of global continuity. In my view, the global stability of the overall street network is essential to maintain a sense of continuous urbanism.

The stability of the global syntactic structure can be jeopardized by the presence of two elements that are related: blocks that are too large and private access cul de sacs are used to provide access to their interior. The morphology of block per se is not the issue; what matters more is the tendency to not created new streets that coherently traverse and subdivide the block when land subdivisions are implemented. Access cul-de sacs express the non-fragmentation of large blocks; they add accessibility to the street network without adding connectivity. If the street is thought of in terms of the succession of road segments, it is possible to specify variations along a street depending on the surroundings. Urban form could then provide a balance between a global syntactic stability of the street network and the adaptation of its parts to the evolution of the building types and function. This is not possible when many properties came to be related to access cul-de-sacs rather than streets. Access cul-de-sacs are inherently linked to the buildings they serve more than to the structure of the surrounding street network as a whole.

As planned by Doxiadis and discussed in chapter 2, Islamabad is, in my view, an interesting example where the hierarchy of streets within a mega block provides a sense of response to certain types of land-uses: from the main through streets serving and enclosing the main public functions to the cul-de-sac serving the residential parts. Streets, however, are bounded by a system of highways that acts a rigid and strong boundary that isolates one sector from the next; furthermore, streets are of a definite type with no chance of evolving into a different one. This is not a flexible system. In sprawling patterns, similar definite types are implemented, in single-family subdivisions for example.

This thesis has hypothesized that the syntactic street structure co-varies but also affects building presence and building configurations more than block morphology considered in isolation. Certain syntactic urban conditions are more favorable to development. This does not mean that development will happen; rather, the syntactic structure of streets and block morphology provide pre-existing conditions that can be capitalized on. As shown in this thesis, building frontage is associated with high connectivity; a block that is well connected to its surrounding will tend to be built more on its edges. However, when connectivity is uneven along the block boundary, the overall amount of frontage lowers. This might be explained by the difference between block-faces with high connectivity and therefore high frontage versus block-faces with lower connectivity with lower frontage. To support this explanation, it has been shown that as blocks become associated with different levels of connectivity along their faces, they become associate with different types of building frontages. These findings suggest that blocks that front diversified streets by connectivity also tend to accommodate diversified building configurations. Herein lies a first clue as to how to design for diversity.

Therefore, assessing urban form by block-face can determine the potentials at both connectivity and continuity levels. Block-faces are indexes that can help to assess the blocks' participation to the global dynamic of the city. They are also the elements from which the sense of continuity of urban form is built up. Given an urban form with very low building density, it is essential to concentrate the efforts of urbanization to the most promising places. The methods and evaluations presented in this thesis make a contribution towards assessing where these places are and what are their characteristics.

Assessing urban form: Atlanta

To assess urban form and more specifically Atlanta, some general principles are recalled to provide a sense of how street, block and building relate with each other. In this dissertation, it has been shown that urban form made of small blocks will have a higher coverage of building, but it will also have a higher coverage of street as a proportion of the size of its blocks. The building coverage of blocks increases until it reaches a level of saturation. Saturation occurs when space between buildings is not sufficient to accommodate another building. In principle, buildings can aggregate until the block attains zero fragmentation along its edge. The same phenomenon applies to building frontage.

The shape of blocks makes some building configurations less likely, it limits what is possible. Some sizes and shapes provide a better fit for their buildings. For example, buildings will tend to be located deeper in the block – deep setbacks – in large, irregular and elongated blocks and as a result, the building density combines low coverage with low fragmentation. However, the location of buildings towards the center of these blocks does not allow for more densification at the edge without adding streets in order to access the existing buildings. Adding internal streets will affect the local network connectivity and change the configurational properties of the peripheral streets. Regular blocks that are small or medium are providing the ground for building configurations with higher coverage but less variations of building configurations. These blocks tend also to be more connected to their context that is in turn more homogeneous.

The urban form of Atlanta can be characterized as diverse. While Atlanta is made of a majority of small and fairly regular blocks, as shown in the two profiles, the extremely large blocks participate fully as elements of discontinuity. The discontinuity of the urban fabric is one of the main characteristics of the overall urbanism of Atlanta. The second characteristic is the amount of building and street coverage. They are extremely low overall and constitute less than 25 percent of the overall land. The fact that there is more street surface than building surface underlines one of the main dilemmas of Atlanta: socio-economically it is a city but formally it has more the characteristics of suburbia. Building configurations in Atlanta are characterized by very deep setbacks that do not participate in defining the continuity of city-form. The two main issues are where to implement new development to create a sense of continuity and how to use the existing potential carried by the street network. Density should be increased for block-faces with high connectivity and building should be located as to create a continuous frontage.

In my view, Colony square block in Figure 84 **Error! Reference source not found.**is an example of a successful large block that addresses the syntactic properties of its surrounding streets, concentrating the density on the main street while achieving a building coverage of only 33 percent. The block belongs to the category of large block (9.9 ha), with 11 block-faces and a span of 541 meters. It carries 43 building of different types according to the street they are facing: Towers and shopping mall are located on Peachtree Street, town-houses and multi-family buildings are facing Midtown and Piedmont park, while single-family houses are facing the residential neighborhood of Ansley Park.

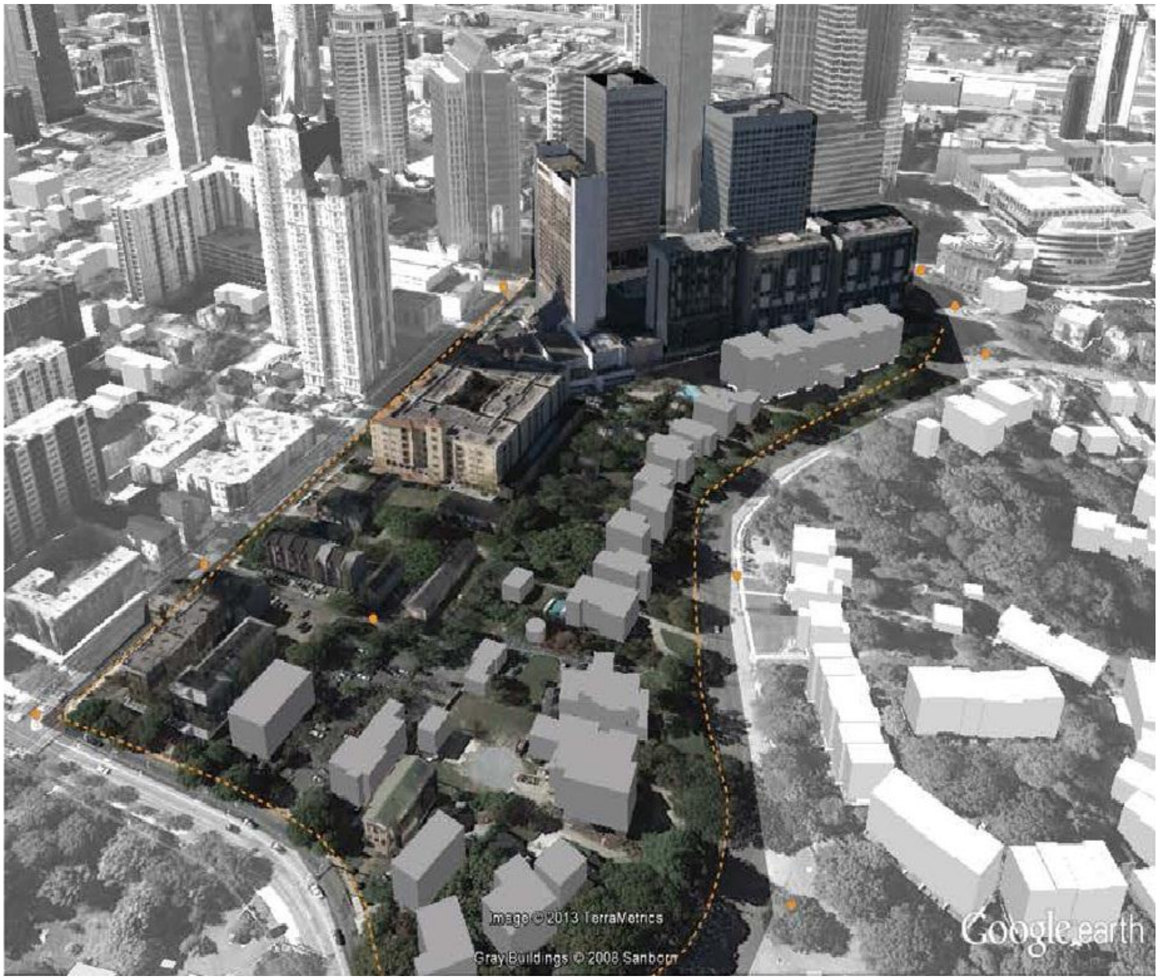


Figure 84. Colony Square block in Atlanta with different types of buildings.

The proposed framework to understand the behavior of existing block-faces concerning building and street loads has shown that block-faces can have different levels of urbanization. However, only some block-faces have more flexibility to accommodate changes, particularly for addition of buildings. The analysis of block-faces has facilitated explorations of the significance of streets in relation to buildings. Streets can now be defined as made of two sides; thus, they link two possibly different conditions emerging from the two blocks they are in contact with. Streets also link adjoining blocks along their length. The context is included in the assessment of block-face.

8.2 Limitations, future research and applications

Some limitations in this work deserve to be addressed and studied in future work

8.2.1 Limitations

A limitation of the thesis is the lack of consideration of zoning as a factor that influences the internal loads of blocks and interacts with, or even takes into account, the patterns of surrounding street network connectivity. While current zoning is available and could relatively easily be brought into the analysis, the present urban form is not the result of current zoning, but of zoning as it has evolved over time. Thus, bringing zoning into consideration is a more complex exercise than it initially appears; dimensions of urban morphological history are entailed. Historical data would be necessary and they are not available. Finding controlled ways to introduce zoning into the analysis will also enrich the preliminary models developed here.

In addition, to be more accurate, building configurations should include the third dimension. Building volumes are not expressed in the study, due to lack of data.

Finally, the effect of property boundaries over time requires further study at a finer scale, taking into account ownership data not presently available. Property lines and lot boundaries are not sufficient information for the purposes of the type of analysis pursued in this thesis: building potential is determined not by plot lines in isolation but by ownership patterns – available maps often preserve property boundaries even when ownership is common. The effects of ownership patterns at a micro-scale will provide a better understanding of how the block is subdivided in parcels and how buildings are located based on these subdivisions. Ownership will be included as a factor that mediates the relationship of block morphology and street network with built form.

8.2.2 Future work

Internal and peripheral street and frontage

Large blocks create potential for more frontage in two very distinct ways: by the length of its perimeter but also by the addition of internal streets. The frontage resulting from internal streets is essentially local and does not participate to the larger network of street connectivity. Syntactically, internal streets act like hallways in buildings and disengage buildings build in the middle of a block from the peripheral roads. Internal frontage is one or more steps away from the larger street network. Access is limited. The peripheral frontage is in direct contact with the larger network of streets connectivity. Future work will clarify the difference between internal and peripheral streets: how it affects the syntactic structure and what are its repercussion on frontage.

Implications for the regulatory frameworks for future zoning

This dissertation focused principally on the morphology of cities and disregarded several factors that have effects on urban form. Land use is maybe the most obvious one and an exploration on how land-use affects building configurations would be appropriate. From the point of view of morphology, the question then would be to examine if certain types of building frontage or coverage are linked to a specific building type as a result of programmatic requirements associated with the type. For example, single-family houses result in a specific pattern of building fragmentation along the frontage that does not lend itself to the creation of composite larger footprints over time. Shopping malls are another special case that requires specifically a large amount of land for its building footprint, the footprints of its parking and the streets to access it. Thus, factoring land use into the discussion will significantly enrich the models presented here.

One can obviously ask whether different types of blocks intrinsically correspond to different zoning categories: for example “single family units” blocks, “multi-family and commercial” mixed use, “commercial and offices” mixed use, “offices single use” and so on. The question will then be asked as to whether this categorization of blocks by land use corresponds to distinctive profiles of footprint sets or distinctive hierarchies of the bounding streets. This exercise becomes particular interesting in the light of a fundamental question in land use planning as it relates to urban design. If land use is zoned by block, then all block boundaries are charged in similar ways from the inside. Where the zoning is different at the adjoining blocks, the street takes the role of a transition between zoning categories. If, on the other hand, blocks are mixed use, one distinct possibility is the natural zoning of land uses by block-face. Zoning by block-face allows the creation of mixed use urban areas where individual streets can still have the same character on both sides and where the differentiation of land uses is a function of the street network and its syntactic structure.

Example of distinctive block-faces in zoning can be seen in the Miami 21 zoning code (http://www.miami21.org/). This form-based code developed for the city of Miami replaces its formal zoning. It differentiates land-use by parcels which allow the code to create a “front” with the parcels located near major roads or edges. Miami 21 zoning code, while providing a first level of frontage for major zones, does not carry such front-back distinctions at the block level, within a zone. A block with differences in accessibility or visibility carries a natural assignation for principal frontage and for back-frontage. Cities need "backs" which provide spaces that are more private without disturbing the overall network. For example, back alleys are used to release the pressure on the major road by fostering services such as picking up trash and delivery.

Miami 21 zoning code provides an exhaustive description on the location of buildings on the parcels, the building density allowed and the possible range of land-uses associated to a parcel. The implementation of such code is missing only one aspect, which is the syntactic impact of streets on the blocks. The streets are classified by types, but they are not evaluated in relation to each other. Understanding the variations along a street or along the edges of blocks brings a more dynamic understanding of cities that goes beyond zones. The larger context can be linked to an individual block or parcel according to the block-face requirements both for internal and external loads.

8.3 Concluding summary

This dissertation has shed light on some purely morphological relationships. It has also proposed to bring block-faces into focus as fundamental to our understanding of city form. In doing so the thesis has also explored ways in which the interface between architectural and urban design can be visualized. Block-faces have emerged as the boundary and interface at which the syntax of street networks and the syntax of built form interact.

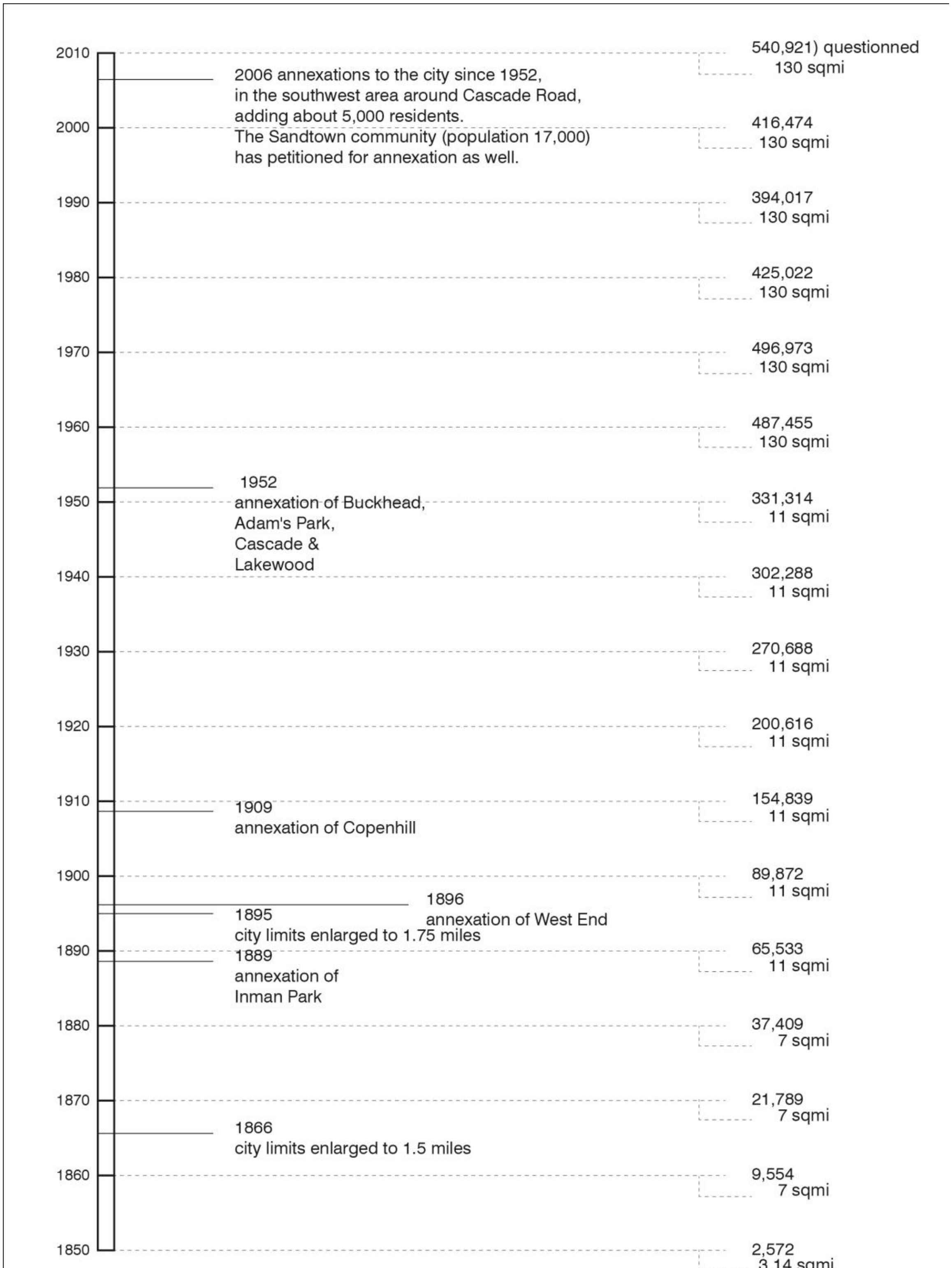
This work contributes to the assessment of existing cities, specifically to the identification of locations with greater potential for development based on good connectivity and good availability of development land at the edge and also in the interior of blocks. The work also contributes to the assessment of the potential of individual properties considered for real estate development. The research conclusions support the idea that zoning should be by street and block-face rather than by block as implemented in form-based codes. However, they also suggest that zoning conditions may vary along the length of a single street based on changing connectivity to the surroundings. Zoning should recognize the identity of streets but also the manner in which streets work as interfaces to the local areas they traverse.

APPENDIX A
POPULATION AND GROWTH OF ATLANTA

(Gibson 1998)

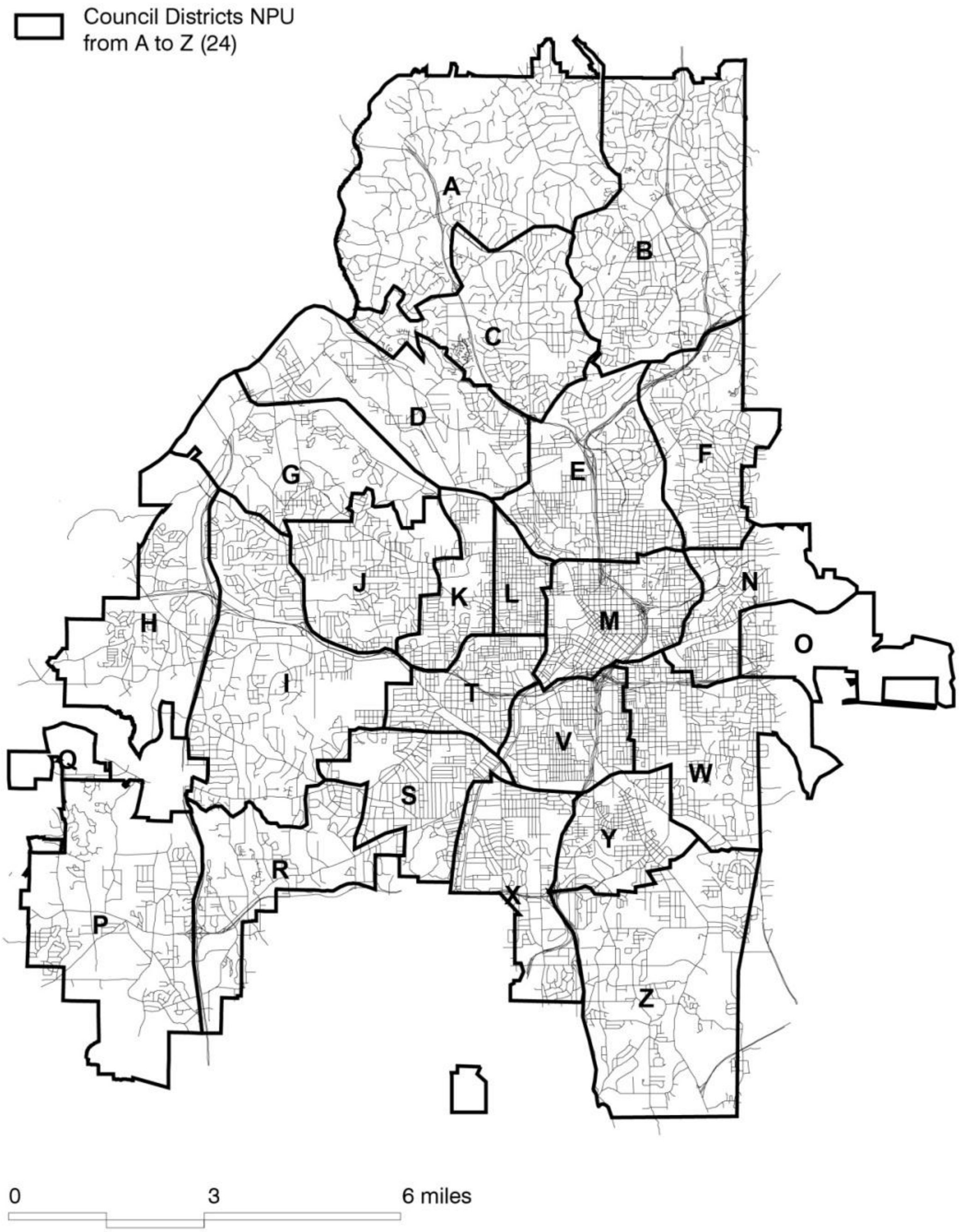
Gibson, C. (1998). Population of the 100 largest cities and other urban places in the United States: 1790-1990, US Bureau of the Census Washington, DC.

"Census of population and housing: decennial census". U.S. Bureau of the Census. 2000. Retrieved 2009-01-01.


2010
540,921) questionned
130 sqmi
2006 annexations to the city since 1952,
in the southwest area around Cascade Road,
adding about 5,000 residents.
The Sandtown community (population 17,000)
has petitioned for annexation as well.
2000
416,474
130 sqmi
1990
394,017
130 sqmi
1980
425,022
130 sqmi
1970
496,973
130 sqmi
1960
487,455
130 sqmi
1952
annexation of Buckhead,
Adam's Park,
Cascade &
Lakewood
1950
331,314
11 sqmi
1940
302,288
11 sqmi
1930
270,688
11 sqmi
1920
200,616
11 sqmi
1910
154,839
11 sqmi
1909
annexation of Copenhill
1900
89,872
11 sqmi
1896
annexation of West End
1895
city limits enlarged to 1.75 miles
1890
65,533
11 sqmi
1889
annexation of
Inman Park
1880
37,409
7 sqmi
1870
21,789
7 sqmi
1866
city limits enlarged to 1.5 miles
1860
9,554
7 sqmi
1850
2,572
3.14 sqmi

APPENDIX B
MAP OF NPU'S

'Neighborhood' is defined by the Atlanta Planning Advisory Board as '*a geographic area either with distinguishing characteristics or in which the residents have a sense of identity and a commonality of perceived interests, or both. Factors that may contribute to neighborhood identity include shared development, history, architecture, social and economic relationships, physical boundaries and the existence of one or more broadly representative neighborhood organizations devoted to neighborhood preservation and improvement*.' (Neighborhood Planning Unit, Leadership Resource Guide, Article B, Section 6-3012 definitions)



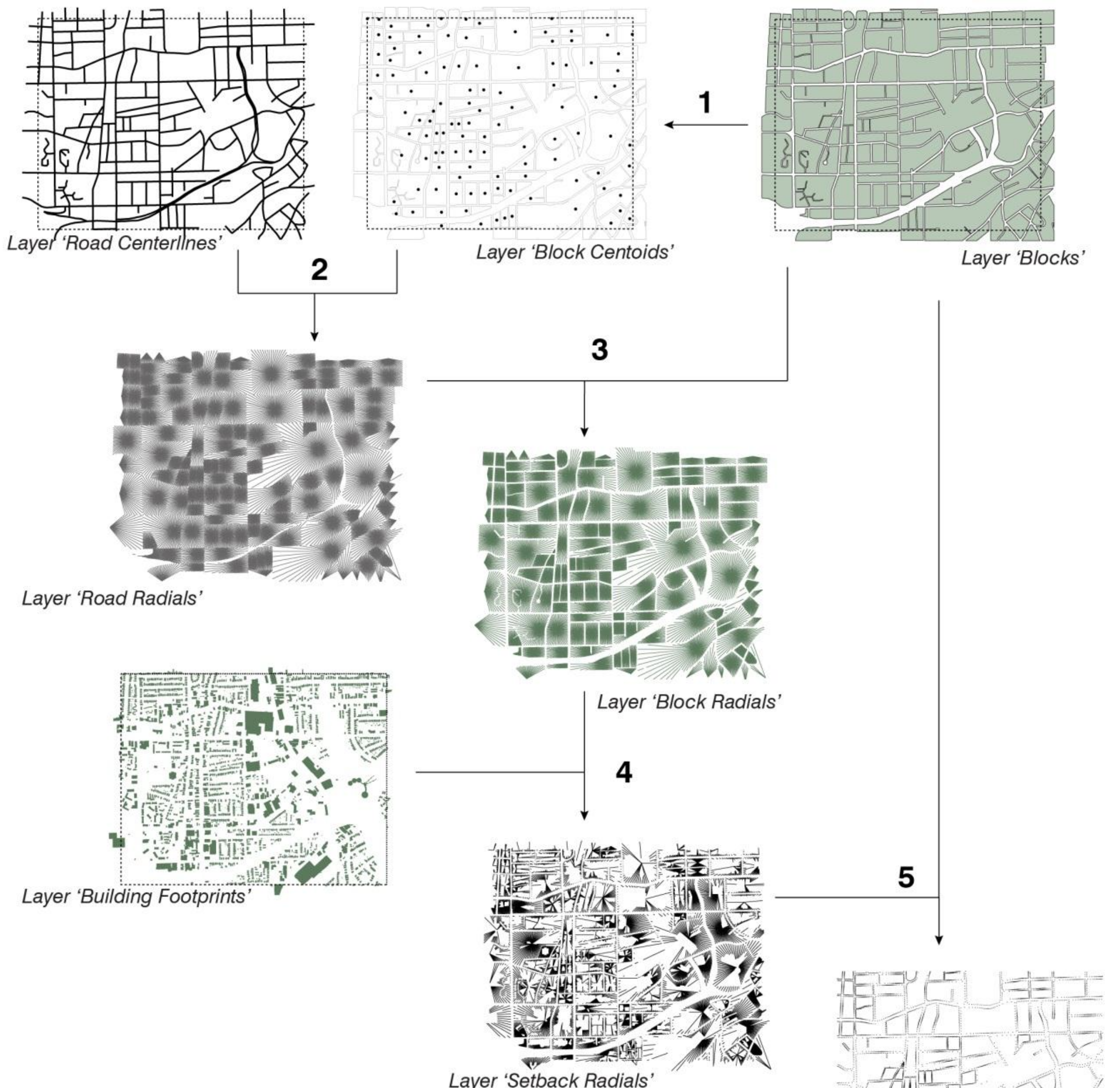
Council Districts NPU
from A to Z (24)
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
V
W
X
Y
Z
0
3
6 miles

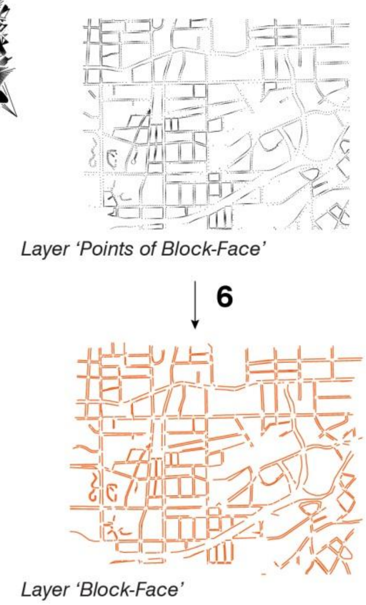
APPENDIX C

FULTON COUNTY BUILDINGS – YEAR BUILT

APPENDIX D

RADIAL ROUTINE





1. create centroids from Blocks that are inside the polygons.

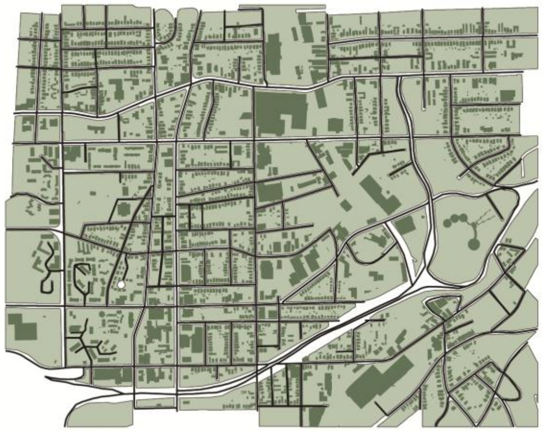
2. Trace radial every 5º angle from centroid to road segment
[alternative method: create points every 5m on road segment and link to centoid]

3. Clip layer 'Road Radials' with layer 'Blocks'

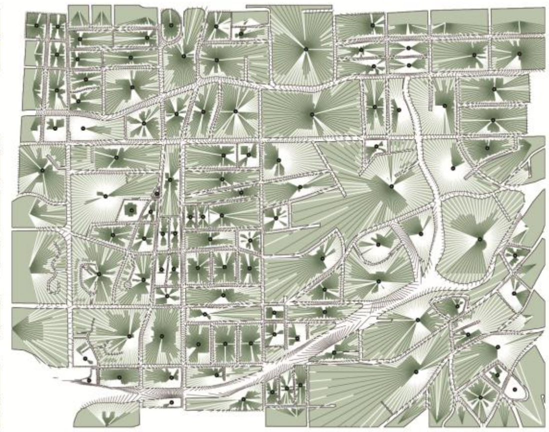
4. Clip layr 'Block radials' with layer 'Building footprints' and keep line in contact with block boundary only.

5. Create points at intersection of block polyline and 'Setbacks Radials'

6. Join with a line 'Points of block-faces' with the same block-face ID



Road segments, Blocks and Buildings



Radials for each element

APPENDIX E
FIT TEST

The relationship of building to block is tested by comparing the maximum external span of buildings with the maximum internal span of blocks in the “Fit test”.

For blocks, the girth gives the maximum span existing within a block to accommodate another shape, i.e. building footprints. In the comparison of 2 shapes, and to see if the shape with smaller area can be fully contained by the shape with larger area, twice the girth of the larger shape should be greater than the longest axis of the smaller. This test can determine if the polygon of a block can accommodate the polygons of buildings footprints[28].

A value is given to each block shape according to its potential to accommodate the set of building footprint shapes. The measure of block potential is expressed as a percentage of the total building footprints it can accommodate.
The script has been developed by Lu Yi, Ph.D. student from Georgia Tech.

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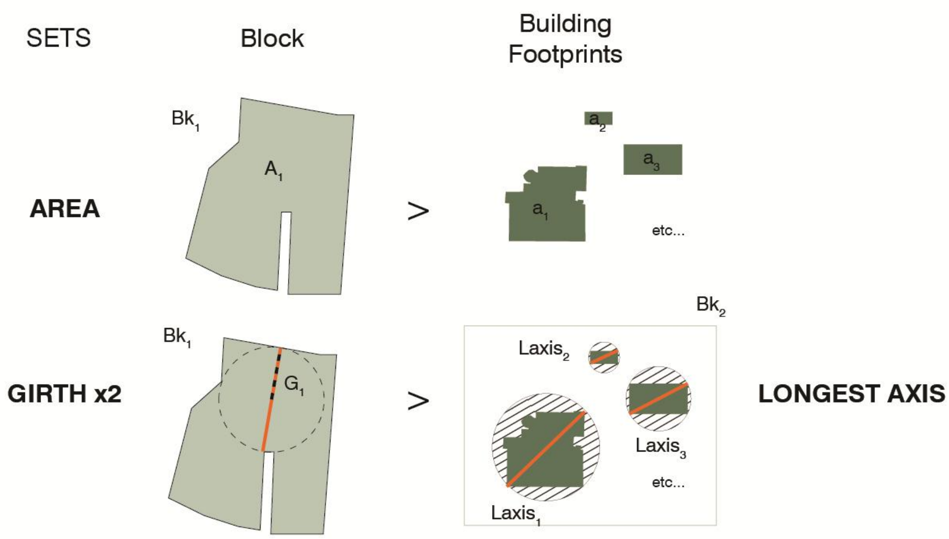
[28] It is different from pilot-study (Vialard 2012) in which only the longest axes were compared, which was not accurate enough.



SETS to be compared:

1. Building Footprints
2. Blocks
3. Building Footprints by Block

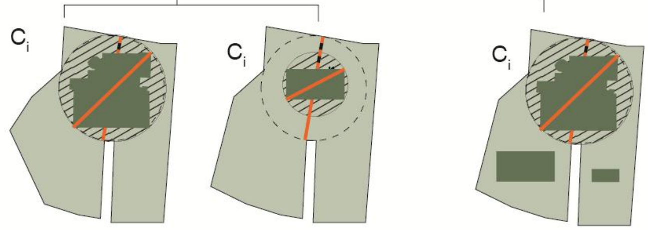
if $A_i > a_n$

if $2G_i > Laxis_n$

if $A_i > \sum^n a_e$

if $2G_i > Laxis_n$*

*the longest Laxis



BY YI LU (March 16, 2010)

```
'Option Explicit
Sub main()

irow = 0 ' row idex for C field.

Do While Cells(2 + irow, 3) <> ""
   'for each row in c field.
   n = 0
   j = 0  'row index for A field.
   Do While Cells(2 + j, 1) <> ""  'loop until value in a field is empty.
      If Cells(2 + irow, 3) < Cells(2 + j, 1) And Cells(2 + irow, 4) < Cells(2 + j, 2) Then
n = n + 1  'add more conditions if need before 'Then'
   j = j + 1
   Loop
   Cells(2 + irow, 5) = n

   irow = irow + 1

Loop

End Sub
```

Script to develop: Each footprint defined by C1 (area) and D1 (range) is compared to each Block defined by Ai (area) and Bi (range), if criteria met 1 if not 0, then sum of all met criteria.

Count if : C1 < A1 and if D1 < B1 1
Count if : C1 < A2 and if D1 < B2 1

Count if : C1 < Ai and if D1 < Bi 1

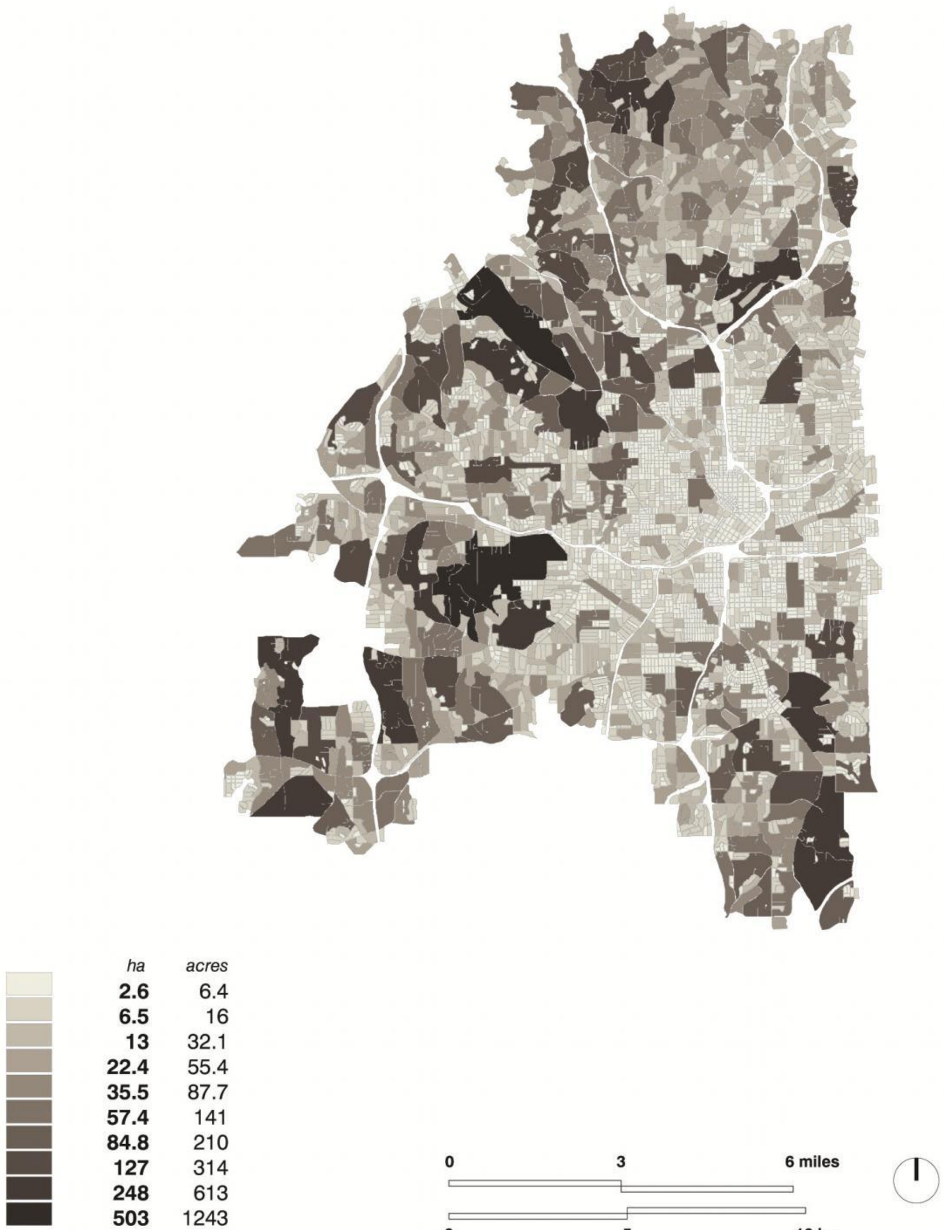
Sum

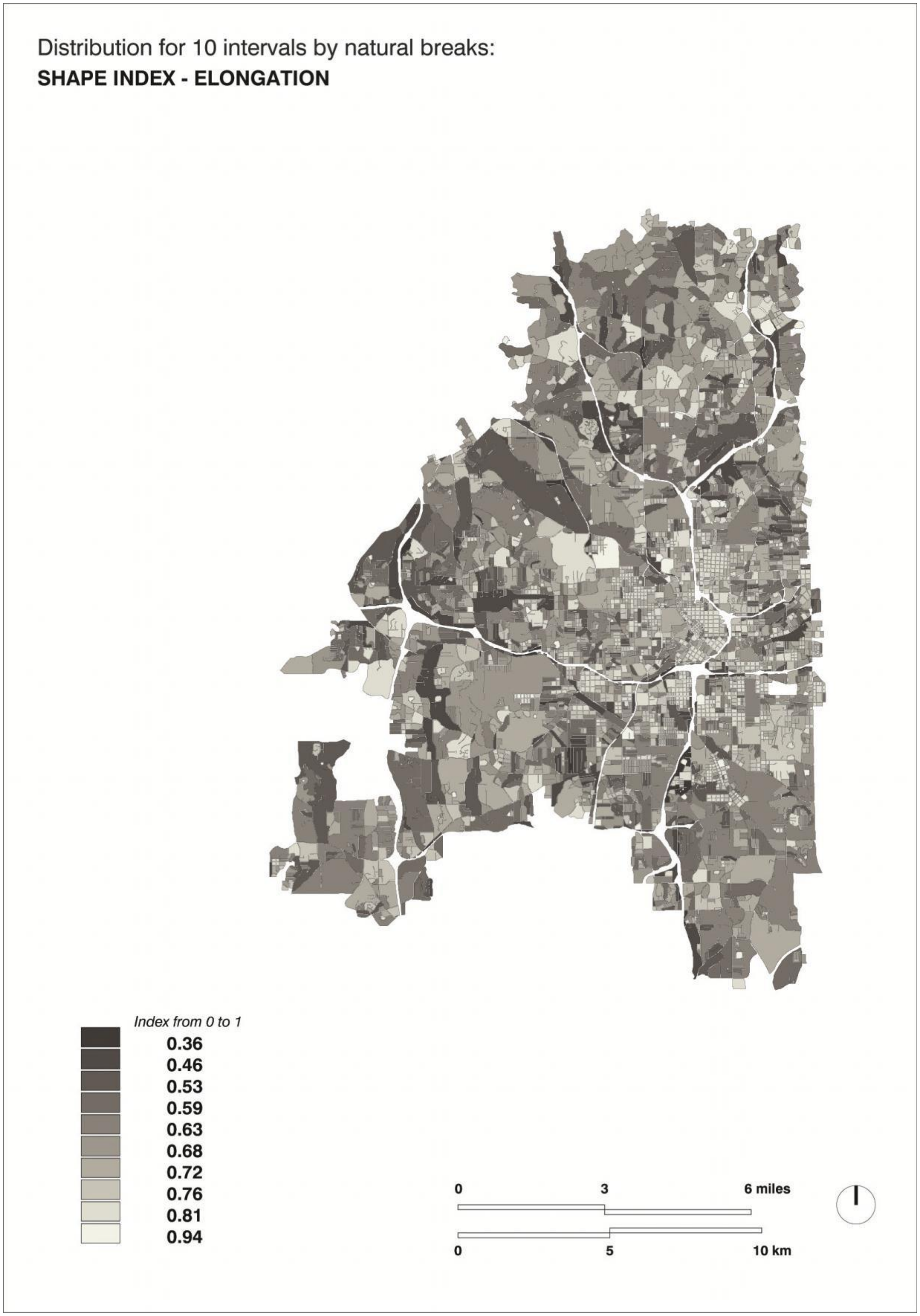
Column A: Block	area	of	city 1
Column B: Block	range	of	city 1
Column C: block	area	of	city 2
Column D: Block	range	of	city 2

Distribution for 10 intervals by natural breaks:

BUILDING AREA : n = 108 455, total area = 2 880 ha, 7 116 acres

Distribution for 10 intervals by natural breaks:
BLOCK AREA : n = 4028, total area = 24 789 ha, 61 255 acres

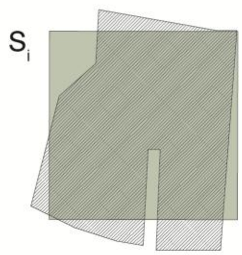



Distribution for 10 intervals by natural breaks:
SHAPE INDEX - ELONGATION
Index from 0 to 1
0.36
0.46
0.53
0.59
0.63
0.68
0.72
0.76
0.81
0.94
0
3
6 miles
0
5
10 km

APPENDIX F

SHAPE INDEXES

Compactness to a square [Cpct]



S_i is the square which has the same area of the shape I. (hatched = shaded)

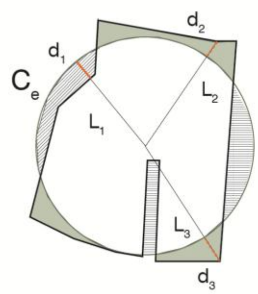
L_i is the side of a square of area a_i and Perimeter p_i.

$A_i = L_i^2$

$P_i = 4 \cdot L_i$

$$[Cpct]_i = \sqrt{A} / P^2 = 16 \cdot a_i / p_i^2$$

Normalized Dispersion [Disp]



d_e is the distance between shape perimeter and the circle perimeter along a radial emanating from the centroid.

C_e is the circle which has an equal dispersion value than the shape.

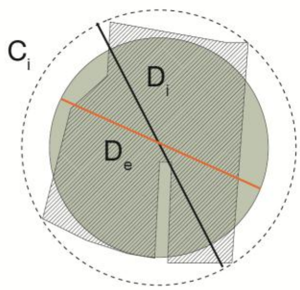
$$\text{dispersion} = \frac{L_1 + L_2 + \ldots L_n}{n}$$

$$\text{deviation} = \frac{d_1 + d_2 + \ldots d_n}{n}$$

(hatched = shaded)

$$[Disp]_i = \text{dispersion - deviation / dispersion}$$

Normalized Elongation [Elon]



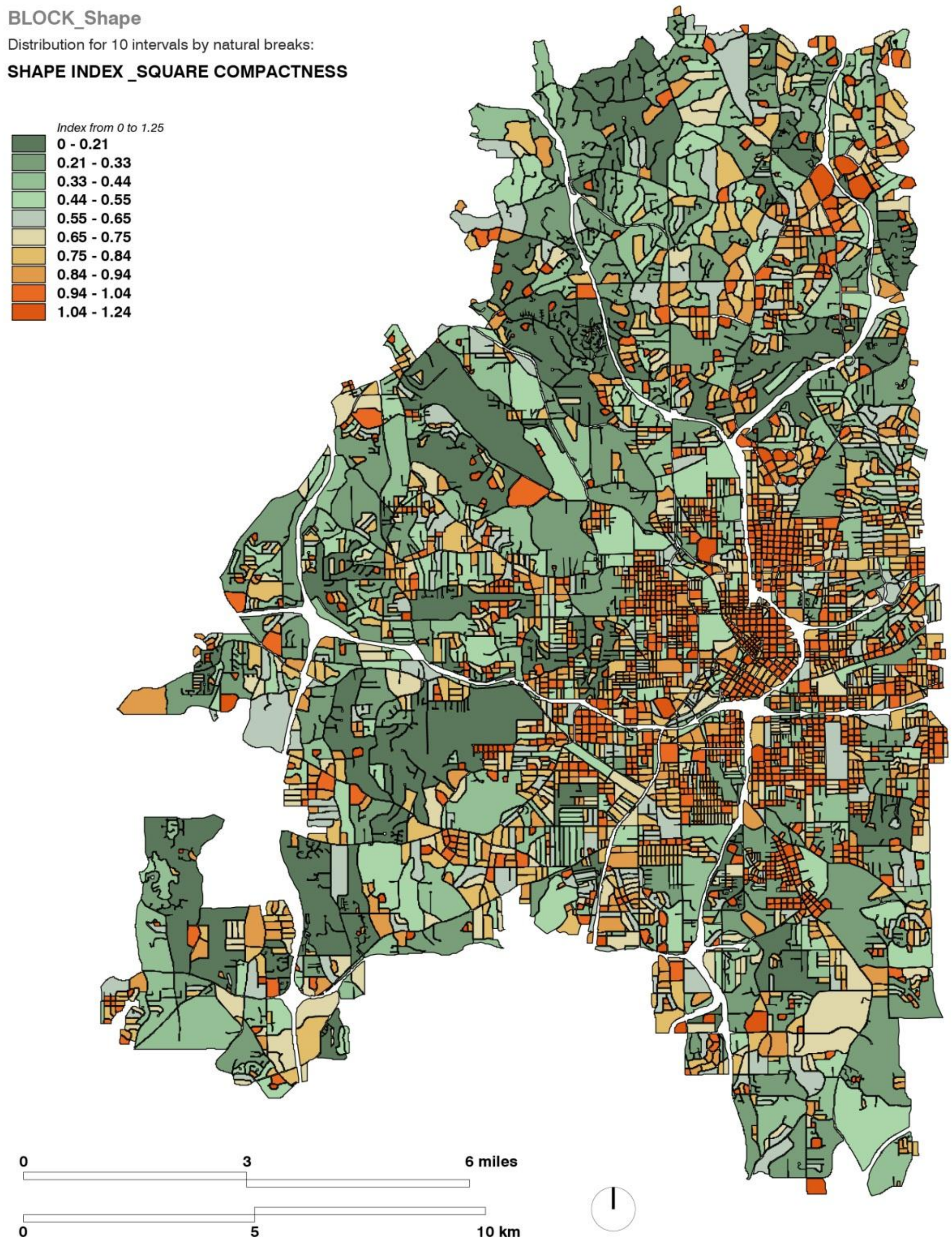
D_i is the diameter of the smallest circle that circumscribes a shape I.

D_e is the diameter of the circle of equal area of a shape

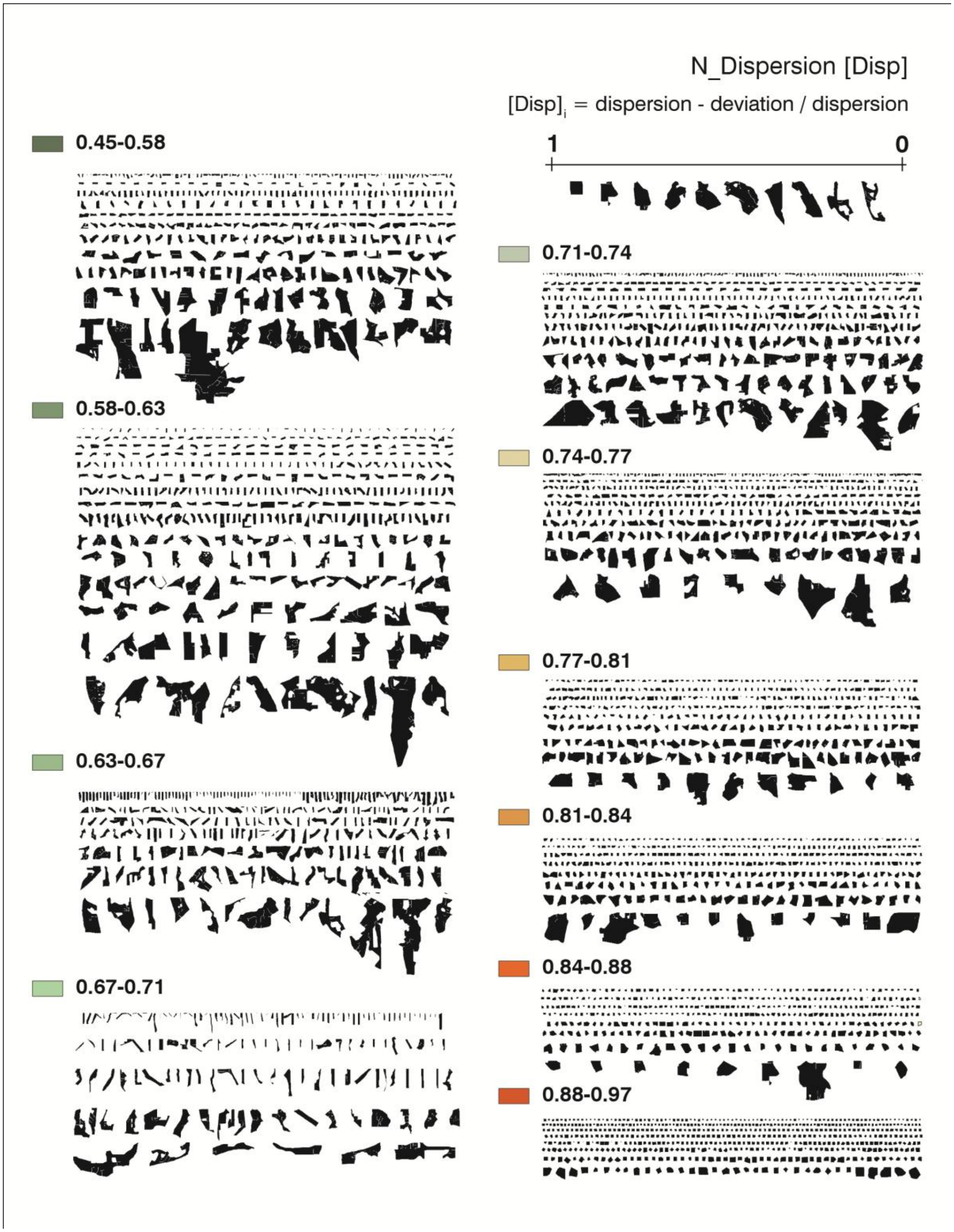
$D_e = 2 \cdot \sqrt{(A_i / \pi)}$

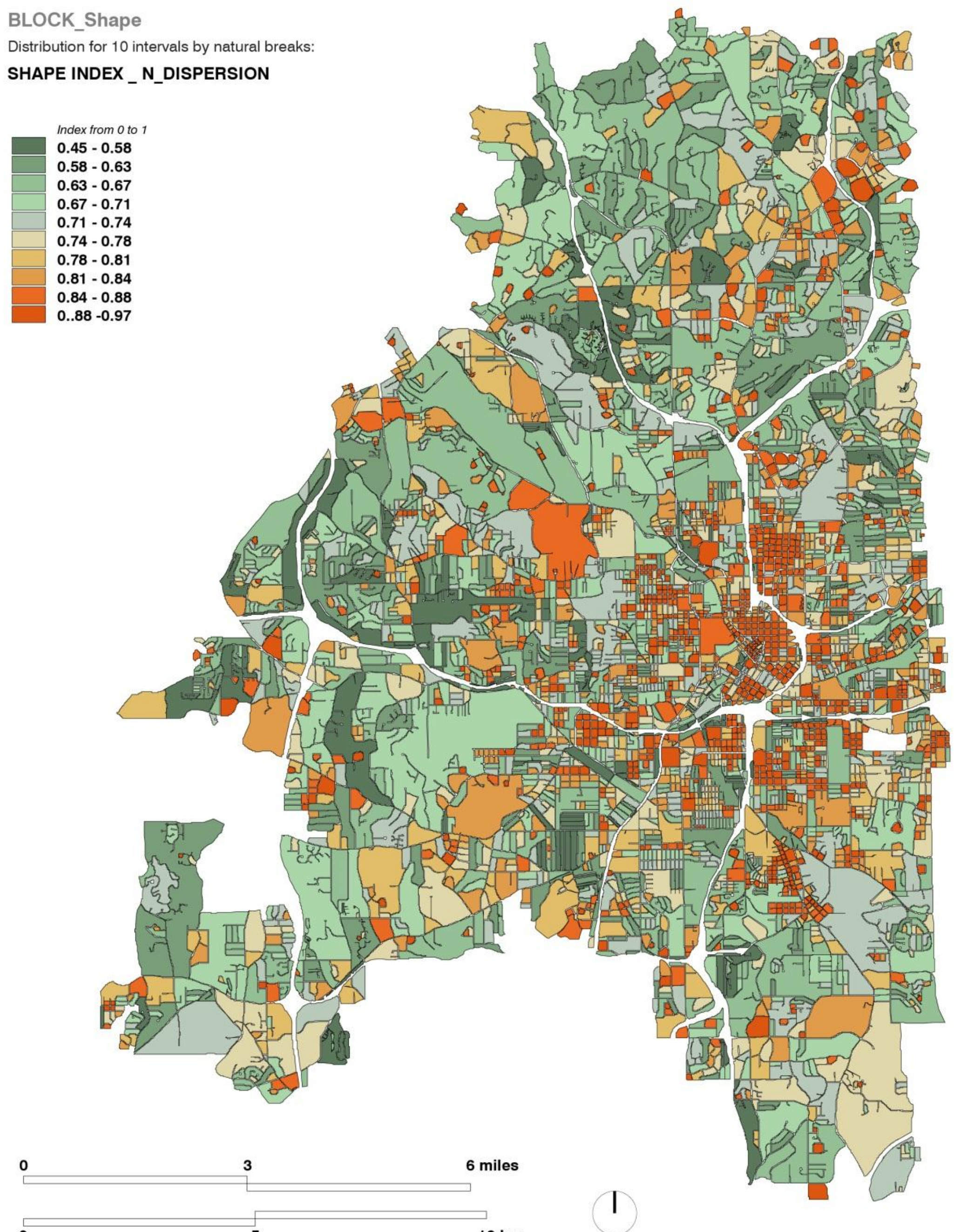
$$[Elon]_i = D_e / D_i = 2 \cdot \sqrt{(A_i / \pi)} / \text{longest axis}$$


Square Compactness [Cpct]
[Cpct]$_i$ = area$_i$*16 / perimeter$_i^2$
1.2
1
0
0-0.21
0.21-0.33
0.33-0.44
0.44-0.55
0.55-0.65
0.65-0.75
0.75-0.84
0.84-0.94
0.94-1.04
1.04-1.24

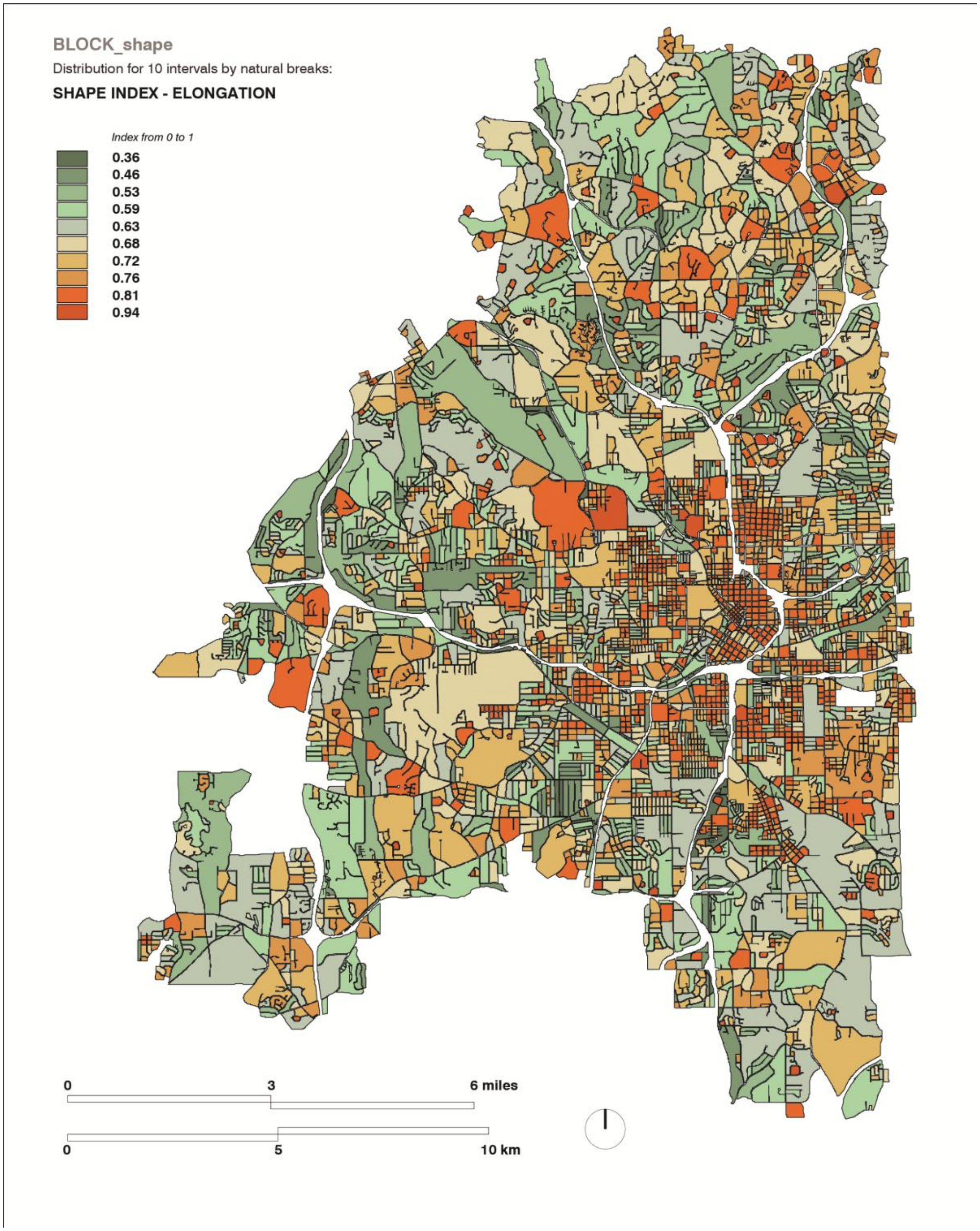


BLOCK_Shape
Distribution for 10 intervals by natural breaks:
SHAPE INDEX _SQUARE COMPACTNESS
Index from 0 to 1.25
0 - 0.21
0.21 - 0.33
0.33 - 0.44
0.44 - 0.55
0.55 - 0.65
0.65 - 0.75
0.75 - 0.84
0.84 - 0.94
0.94 - 1.04
1.04 - 1.24
0
3
6 miles
0
5
10 km


N_Dispersion [Disp]
[Disp]$_i$ = dispersion - deviation / dispersion
1
0
0.45-0.58
0.58-0.63
0.63-0.67
0.67-0.71
0.71-0.74
0.74-0.77
0.77-0.81
0.81-0.84
0.84-0.88
0.88-0.97


BLOCK_Shape
Distribution for 10 intervals by natural breaks:
SHAPE INDEX _ N_DISPERSION
Index from 0 to 1
0.45 - 0.58
0.58 - 0.63
0.63 - 0.67
0.67 - 0.71
0.71 - 0.74
0.74 - 0.78
0.78 - 0.81
0.81 - 0.84
0.84 - 0.88
0..88 -0.97
0
3
6 miles
0
5
10 km

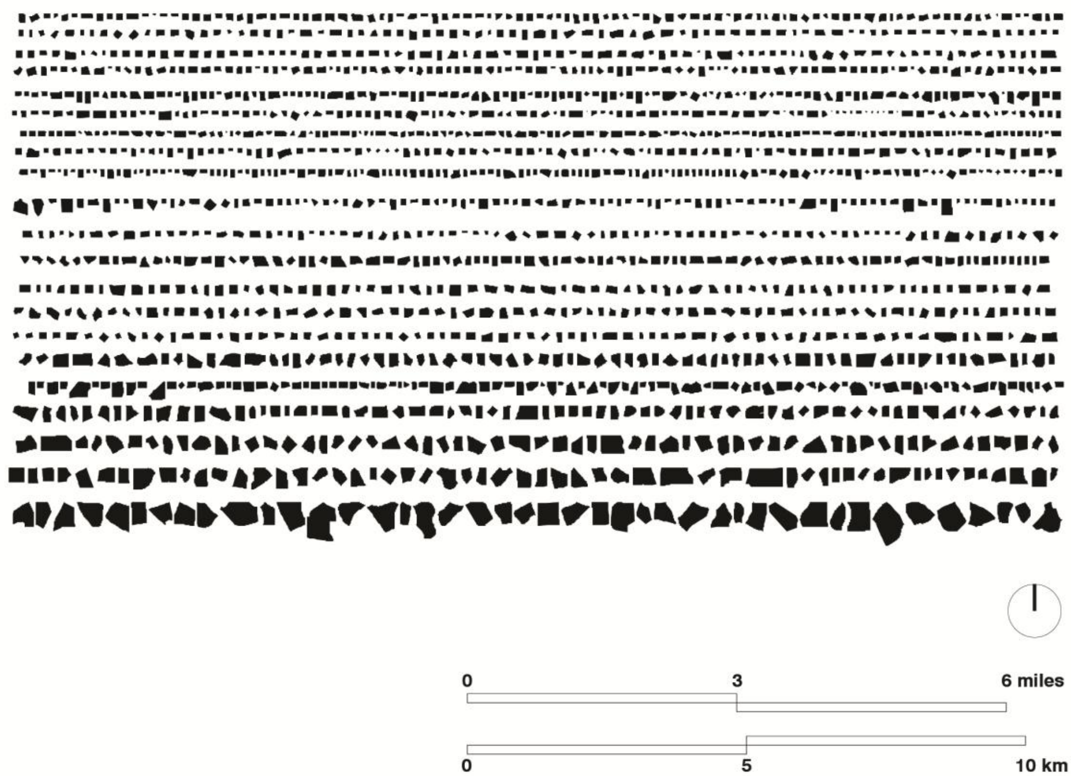

Elongation [Elon]
$[Elon]_i = D_e / D_i = 2 \cdot \sqrt{(A_i / \pi)}$ / longest axis
1
0
0-0.36
0.36-0.46
0.46-0.53
0.53-0.59
0.59-0.63
0.63-0.68
0.68-0.72
0.72-0.76
0.76-0.81
0.81-0.94


BLOCK_shape
Distribution for 10 intervals by natural breaks:
SHAPE INDEX - ELONGATION
Index from 0 to 1
0.36
0.46
0.53
0.59
0.63
0.68
0.72
0.76
0.81
0.94
0
3
6 miles
0
5
10 km

APPENDIX G

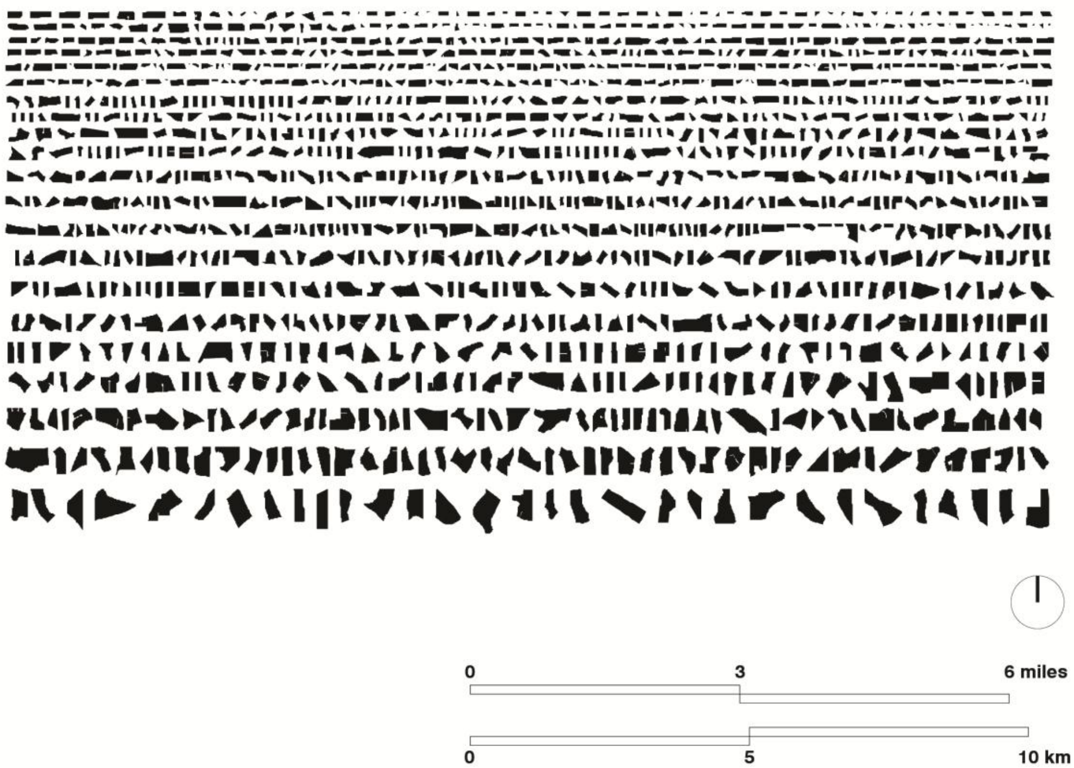
MORPHOLOGICAL CLUSTERS

Cluster 8 *Faces:* 4 - *Width:* 100m - *Span:* 200m



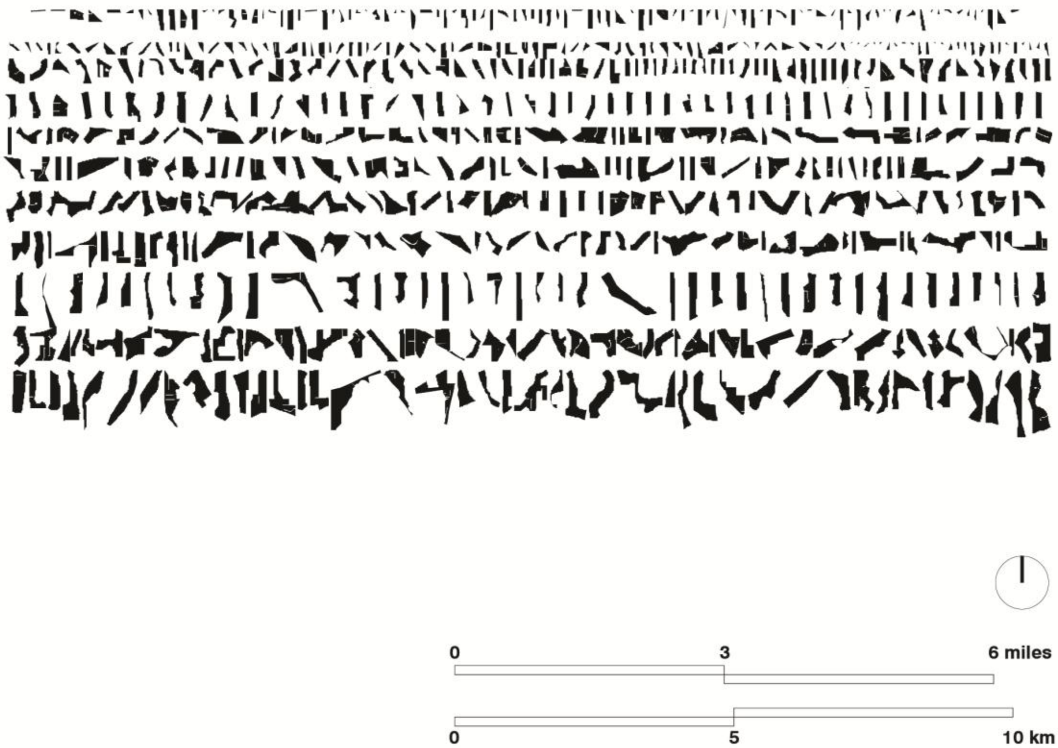
Cluster ID	*Number of blocks*	*Mean Area*	*Mean Compactness*	*Mean Elongation*
8	1761	**2.12** *ha*	**0.96**	**0.75**

Cluster 7 Faces: 5 - Width: 130m - Span: 300m



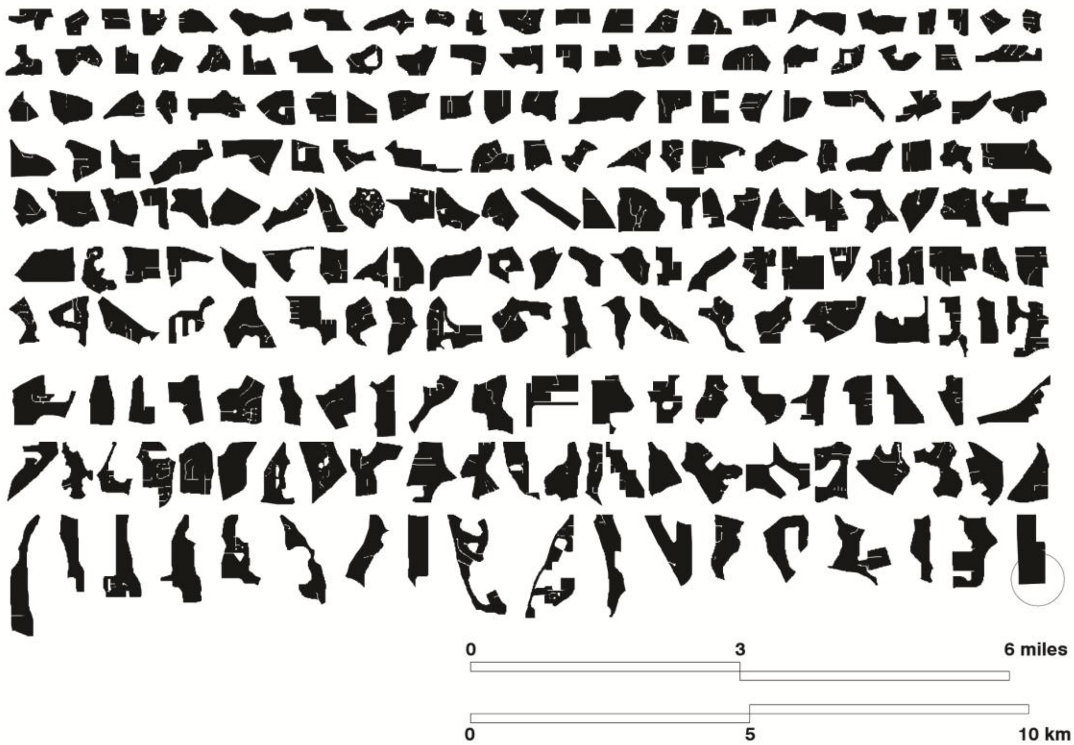
Cluster ID	Number of blocks	Mean Area	Mean Compactness	Mean Elongation
7	1352	**3.31** *ha*	**0.76**	**0.63**

Cluster 1 — *Faces:* 7 - *Width:* 160m - *Span:* 440m

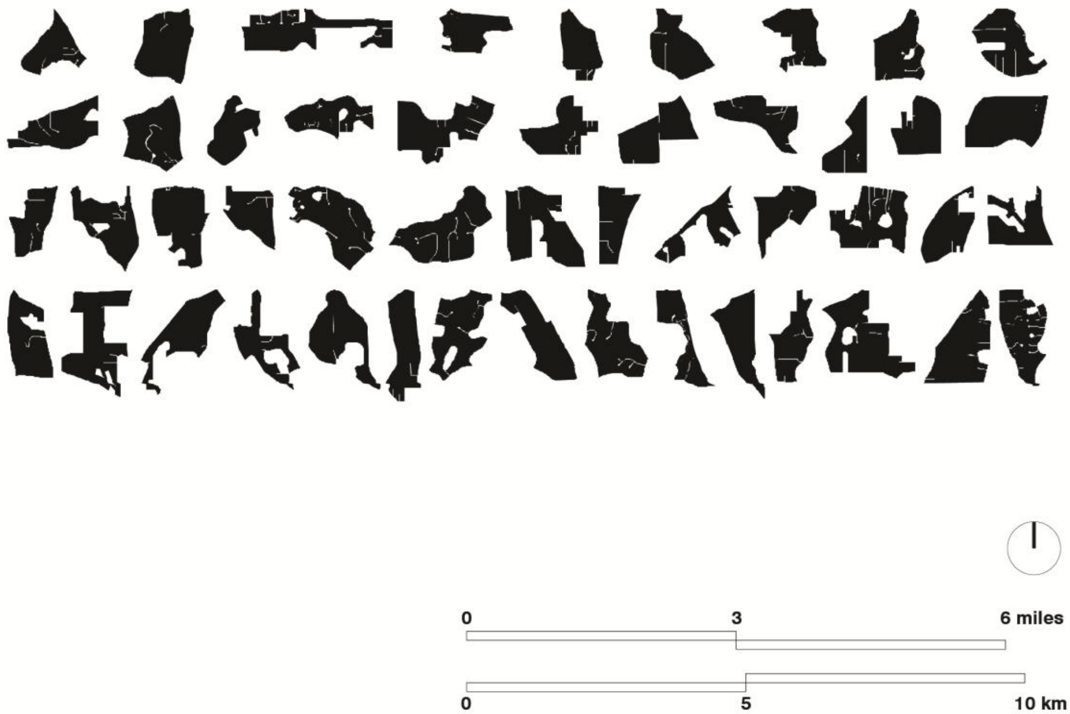


Cluster ID	Number of blocks	Mean Area	Mean Compactness	Mean Elongation
1	638	**4.7** *ha*	**0.49**	**0.5**

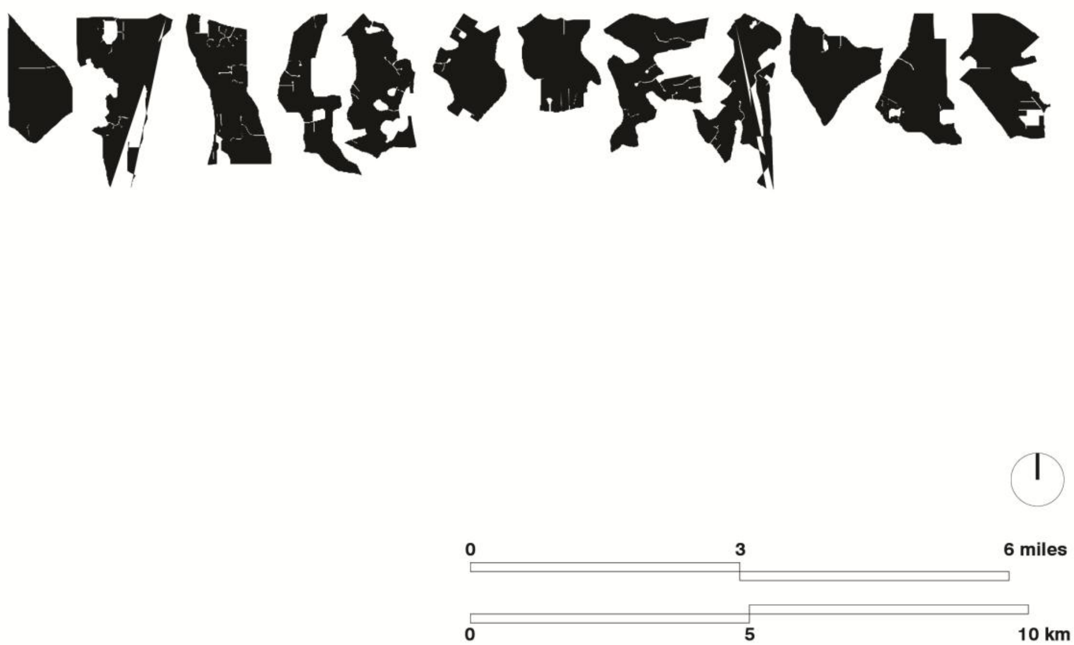
Cluster 2 — *Faces:* 20 - *Width:* 230m - *Span:* 1km



Cluster ID	Number of blocks	Mean Area	Mean Compactness	Mean Elongation
2	213	**30** *ha*	**0.39**	**0.63**

Cluster 3 *Faces:* 30 - *Width:* 260m - *Span:* 1.7km

Cluster ID	*Number of blocks*	*Mean Area*	*Mean Compactness*	*Mean Elongation*
3	48	**85** *ha*	**0.31**	**0.62**

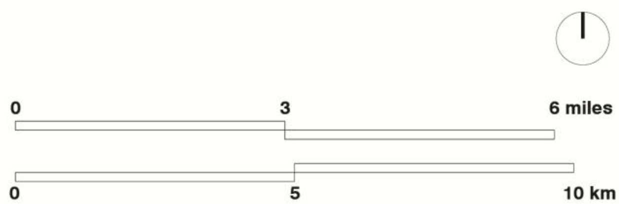
Cluster 6 *Faces:* 50 - *Width:* 320m - *Span:* 2.7km



Cluster ID	*Number of blocks*	*Mean Area*	*Mean Compactness*	*Mean Elongation*
6	12	**190** *ha*	**0.23**	**0.60**

Cluster 4 *Faces:* 120 - *Width:* 360m - *Span:* 4km

Cluster 5 *Faces:* 66 - *Width:* 360m - *Span:* 4.1km



Cluster ID	*Number of blocks*	*Mean Area*	*Mean Compactness*	*Mean Elongation*
4	1	**503** *ha*	**0.08**	**0.64**
5	1	**346** *ha*	**0.17**	**0.51**

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