Measuring the Scale, Density and Directness of American Cities

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Abstract

Cities, planning departments, and design firms are becoming more interested in promoting measures to increase the connectivity of street networks. As a result, new design guidelines have been recommended, regulations have been adopted, and yet, a clear, comprehensive understanding is still lacking for the existing environments we seek to change. This research documents the measures of 584,561 road segments and 173,511 blocks from 4,321 local areas across 24 of the most populated American cities. It also provides a means for assessing the measures of existing conditions in the American city – their central tendency and variability, relative to the suggested guidelines proposed in for practice. It provides a fundamental sense of the scale, density and directness of the road segments and blocks, as configured to form the texture of the urban fabric encountered across these American cities. Lastly, and perhaps more importantly, this work illustrates that the scales of road segment length and block area measured substantially less than the suggested maximum allowable given in the regulatory policies, and yet their density was still remarkably low. In conclusion, it calls for a review of the measures used to describe connectivity, and suggests the use of a measure of density that is contingent on both scale and configuration to policy makers to more accurately predict their desired outcome.

Keywords

street connectivity, urban morphology, street networks, regulations

Introduction

Cities, planning departments, and design firms are becoming more interested in promoting measures to increase the connectivity of street networks. As a result, new design guidelines have been recommended, regulations have been adopted, and yet, a clear, comprehensive understanding is still lacking for the existing environments we seek to change. Much of the planning and transportation research related to street connectivity examines the scale, capacity, and performance of street networks as they relate to land-use distributions. And yet, as this research will demonstrate, these traditional metrics of street connectivity are neither capable of detecting acceptable levels of connectivity, nor are they reflective of the expected differences in connectivity across local areas in these American cities. Unfortunately, regulatory frameworks based on these traditional measures will not be accurate or useful to policy makers in achieving their desired outcomes. Are there measures that could be suggested as guidelines or used within the regulations to insure increases in density? Yes, but it requires a shift from assessing scale to analyzing the morphology of the urban form. It requires the use of a measure that captures the configuration of the road segments within a street network.

Historically, design guidelines have been altered as a result of the evolving trends in the planning and transportation fields, and associated regulatory and legal frameworks, along with their enforcement agencies, have produced significant changes in the structures of urban form (Ben-Joseph, 2005). Evolving theories in the disciplines of planning, urban design, and architecture have produced distinctive approaches toward mandating the scale of a street network, its distribution of land-use, street design, and density (Panerai, Castex, Depaule, & Samuels, 2004). Cultural and social reforms, particularly during the late 19th and early 20th century, have been credited with encouraging forms of suburban growth with lower densities (Reps, 1965). Changing economics in development, particularly those specific to the late 20th century brought about by the modern highway infrastructures, created a new type of city – the edge city, which was intended to be completely isolated from its surrounding context and distinctly different from the traditional urban forms (Garreau, 1991). Changing residential building practices have been cited as having an effect on the increased size of the lot and parcel, subsequently affecting the size of the block (Moudon, 1986). Furthermore, increased interest in the continuity of transportation networks and its associated engineering standards for the safety of the automobile have decreased the connectivity in newer street networks (Southworth & Ben-Joseph, 2003; Wolfe, 1987).

Despite these evolving trends in morphology and the current debate on which measure of street connectivity to use (Dill 2004), practitioners and policy makers have tended to emphasize measures describing the elements of a street network—those of the road segment and block, because they are more easily understood in regulations as a constraint in the design process (Handy, Paterson, & Butler, 2003). Similarly, these measures of length and area also tend to be more easily mandated in policy and applied in evaluating submitted plans. Thus, statistical measures of road segment length, block area, or block face – as a mean or maximum, are preferred in lieu of densities.

Given these preferences, recommendations have been made to assist professionals in creating developments greater in their connectivity, and various policies have been adopted. Specifically, in 1935, the Federal Housing Administration (FHA) recommended a block face[1] ranging in length from 600 to 1000 feet. By 1965, the Institute of Traffic Engineers (ITE) prescribed a maximum length of 1000 feet for cul-de-sacs, defined as road segments penetrating a block without actually

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[1] Vialard (2013) has described the complexities in defining the length of block face using street-centerline data and conflating the term with road segment length. As is common in the literature when using street centerline data, length of block face is equal to length of road segment for a street network consisting of only four-point intersections; however, if an intersection is defined as a T-junction or a three-point intersection, the length of block face will differ for the blocks adjoining either side of the road segment.

subdividing it (Southworth & Ben-Joseph, 2003). More recently, as part of Duany and Plater-Zyberk's drafted T.N.D. Ordinance for Palm Beach County, Florida, the maximum allowable length of a block face was recommended at 300 feet, and the maximum allowable distance for block perimeter was 1300 feet (Krieger & Lennertz, 1991). In the checklist for designing a traditional neighborhood development, Duany, Plater-Zyberk, and Speck (2000) proposed that block faces should be less than 600 feet in length and proposed that block perimeters should be less than 2000 feet. After reviewing policy requirements in several local jurisdictions across the U.S., Handy, Paterson, and Butler (2003) found measures related to block face, requiring a minimum of 300 feet and a maximum of 600 feet in length.

Although many studies have analyzed the measures of street connectivity for neighborhoods with influential historical and planning characteristics (Cervero & Kockelman, 1997; Crane & Crepeau, 1998; Jacobs, 1993; Siksna, 1997; Song & Knaap, 2007; Southworth & Owens, 1993), there have been few systematic reviews of the measures of street connectivity, as encountered randomly across metropolitan areas. Studies have tended to select areas of interest to compare, or contrast, characteristics. Studies have demonstrated that smaller blocks suggest shorter road segments and a greater density of choice intersections (Jacobs, 1993; Peponis, Allen, Haynie, Scoppa, & Zhang, 2007). Correspondingly, studies have demonstrated that shorter road segments suggest more intersections, greater densities, and shorter distances for travel, promoting greater street connectivity and suggesting greater pedestrian activity (Aultman-Hall, Roorda, & Baetz, 1997; Frank et al., 2006; Handy, 1996; Hess, Moudon, Snyder, & Stanilov, 1999; Özbil & Peponis, 2011).

With so much interest in street connectivity, an understanding of these measures is fundamental, and measures of the existing street networks in the American city should be documented relative to the suggested guidelines proposed in the literature. If we accept the notion suggested by Handy et al. (2003) that higher street connectivity is desirable, then it is important to understand the range of these measures – their central tendency and variability, before mandating them within those frameworks and associated policies intent on impacting urban development.

Defining Street Connectivity

Many measures have been used to describe street connectivity and the distinctive properties of a street network (Dill, 2004; Marshall & Garrick, 2009). Most are focused on calculating the scale, density, or directness of road segments, blocks, and nodes contained within a network to link morphological and functional aspects for comparison. Researchers have studied scale by analyzing measures of the block—its area, perimeter, compactness and the length of each block face. Related to density, researchers have studied the number of blocks, road segments, and nodes for each area of interest, considering both the density of intersections and the ratio of intersections to cul-de-sacs. Related to directness, researchers have studied characteristics of the street network—such as the distance and directness between potential points of destinations.

To add to the more traditional measures in the planning and transportation literature, two new measures—metric reach and directional distance—have been introduced to study the density of road segments as they are configured relative to scale (Peponis, Bafna, & Zhang, 2008). Metric reach is defined as the sum distance captured when moving outward from the center point of each road segment in all possible directions until a set distance is reached. Correspondingly, directional distance is defined as the average number of changes in direction necessary to navigate that distance captured by metric reach, with each change in direction defined parametrically as a minimum angle. So, unlike measures that calculate averages or densities to describe a street network in general terms, metric reach—and its associated measure of directional distance—yields a measurement that describes the individual road segment in relation to the density and directness of the surrounding context. It assesses not only connectivity but configuration as well. Furthermore, metric reach describes connectivity as a potential within a structure—independent of land-use and any path to a destination of interest, which often shift with evolving trends in development.

Collecting Data

To more broadly measure street connectivity, road segments and blocks are sampled randomly from local areas within 24 of the most populated American cities. These include: Atlanta, Baltimore, Boston, Chicago, Cincinnati, Cleveland, Dallas, Denver, Detroit, Houston, Los Angeles, Miami, Minneapolis, New York City, Philadelphia, Phoenix, Pittsburgh, Portland, San Diego, San Francisco, Seattle, St. Louis, Tampa, and Washington D.C.[2] Methodologically, a random sample of local areas was identified for each of these 24 cities, using an independently defined framework for each city to ensure an even distribution and equitable probability of selection (Figure 1).[3]

From each local area, road segments, blocks, and their associated measures were extracted using the geoprocessing tools available from Esri. For consistency, those road segments and blocks that were 'completely contained within' and those that 'intersected' the boundary of each local area were extracted from the larger context of the city (Figure 2).[4] This automated process unintentionally created several limitations,[5] and it captured significantly more area than was originally intended.[6] Nevertheless, in summary, the resulting, random sample captures 584,561

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[2] Initially, each city was defined simply by the legal boundary of its larger Metropolitan Statistical Area (MSA); yet in several cases, the overall density of the city was continuous across the landscape from one MSA to another. In these cases, the two MSAs were combined to more accurately capture the morphology of the city. These combinations include the union of Cleveland with Akron, Denver with Boulder, Los Angeles with Riverside and Ventura, Philadelphia with Trenton, and San Francisco with San Jose.

[3] For each city, the framework was defined by a point of center, radiating rings that established distance from that point of center, and a coordinate system to delineate direction. The point of center was established by the position of the original City Hall or a similar politically significant building. The rings radiated outward at five-, fifteen-, thirty-, and sixty-mile intervals (French & Scoppa, 2007). The coordinate system, fixed by the point of center, was superimposed and rotated forty-five degrees to define North, South, East, and West quadrants. From each section of this established framework, x and y coordinates were randomly selected at a distance and degree from the designated center, and a provision was included to eliminate the potential of overlapping areas. Pairs that fell outside the political boundary of the MSA, given its irregularity within undeveloped areas, were discarded.

[4] The automated process for selection allowed for the creation of a larger set of samples than otherwise would be possible, but in doing so, it generated several complications. The aggregate size of the random sample made it impossible to examine the data to correct errors. As a result, the random sample was only as good as the original set from which the data was drawn, without interventions to correct inaccuracies.

[5] Not all road segments surrounding the selected blocks were captured in this automated process therefore any assessment of the averages calculated for each local area should be considered carefully.

[6] Extremely large blocks and long road segments in areas yet to be developed were captured as a consequence of the U.S. Census Bureau's method in defining a MSA by county boundaries. Similarly, small extremes, or residuals resulting from the way in which the Esri maps were drawn, were also captured. The inclusion of such extremes, at either scale, greatly affected the statistical summaries, distributions, and confidence in the inferences. As a result,

road segments and 173,511 blocks from 4,321 local areas across these 24 American cities. It provides a means for assessing the measures of existing street networks in the American city—their central tendency and variability. In summary, it yields measures in a broad context, capturing historical, planning, and geographical distinctions previously acknowledged but not fully, quantitatively documented in the literature.

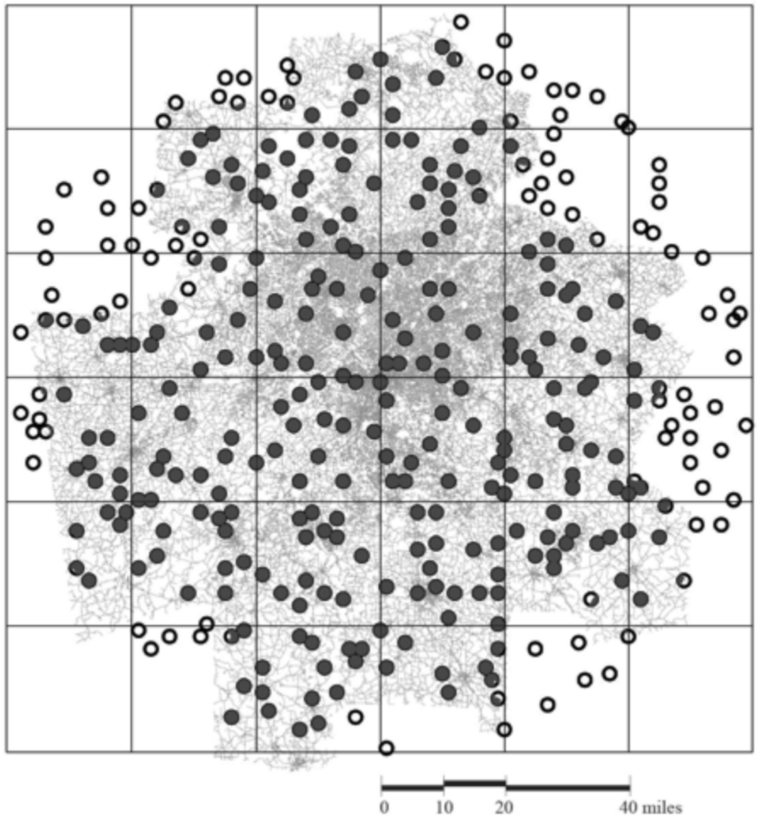

Figure 1
Illustration of the Local Areas sampled in Atlanta. Discarded local areas, or those with a boundary that not capturing development, are shown without shading.

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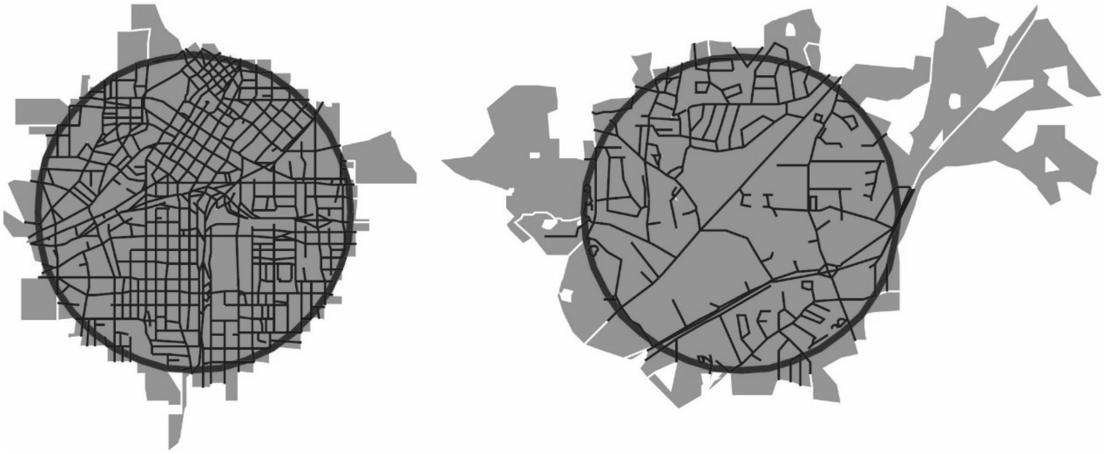
road segments and blocks of extreme scale, both large and small, were identified and excluded to ensure more discerning conclusions from the subsequent statistical analysis. To prevent potential distortion from these extremes within the database, the work of Thomas Jefferson and his influence on the Land Ordinance of 1785 (Rashid, 1996) was assessed in conjunction with the work of Doxiadis (1965) and Krier (1976) to set parameters for pragmatically defining and removing extremes. Blocks more than 640 acres in area or less than 0.12 acres were excluded. Similarly, road segments more than 1 mile in length or less than 72 feet were excluded.



(a) Local Area at the Metropolitan Center

(b) Local Area at the Periphery

Figure 2
Illustration of the Blocks, shown in grey, and Road Segments, shown in black, captured by the circular boundary and subsequently extracted to create the random sample of 584,561 road segments and 173,511 blocks

Examining the Statistical Analysis

Initially, measures of length, block area, block perimeter, metric reach, and directional distance are analyzed as statistical means to yield an average. Subsequently, the medians and interquartile ranges are analyzed to determine an expected range. Lastly, the distributions and the intervals of highest frequency, or the interval modes, are assessed to identify the most frequently encountered measures within these selected cities.

For this random sample of 584,561 road segments and 173,511 blocks, as extracted from 4,321 local areas, the mean of length measures 656.15 feet, the mean of block area measures 31.49 acres, the mean of block perimeter measures 3,854 feet, the mean of metric reach measures 23.39 miles, and the mean of the directional distance measures 4.55 (Table 1). For each of these measures, the mean is greater than the median suggesting a non-normalized distribution; thus, the interquartile range is also described via first and third quartiles. For road segment length, the first quartile measures 264.12 feet, the third quartile measures 749.06 feet, and the interquartile range of length, or the difference between the first and third quartiles, measures 484.94 feet (Table 2). The interquartile range of block area measures 9.18 acres; the interquartile range of block perimeter measures 1,975 feet; and the interquartile range of directional distance measures 2.79 (Table 2).

Table 1
Mean of Length, Block Area, Block Perimeter, Metric Reach, and Directional Distance, as calculated for the Random Sample of Road Segments and Blocks

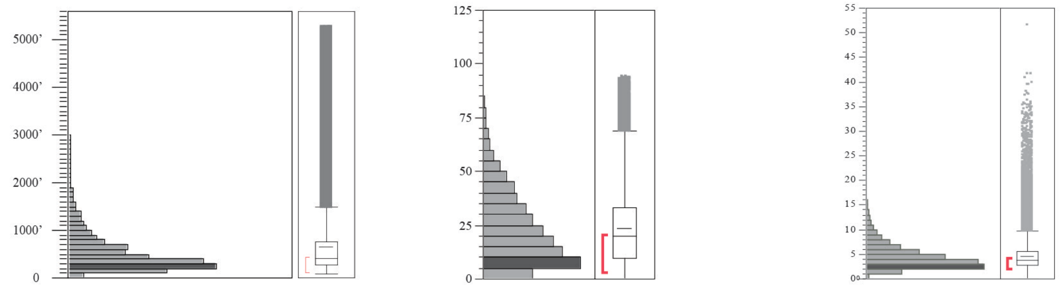
City	Mean of Road Segment Length * (feet)	Mean of Block Area ** (acre)	Mean of Block Perimeter ** (feet)	Mean of Metric Reach at 1mi * (miles)	Mean of Directional Distance at 1 mi/10 degree * (changes in direction)
all Road Segments & Blocks of the Random Sample	656.15	31.4932	3853.99	23.3893	4.55

* (n) = 584, 561 road segments
** (n) = 173,511 blocks

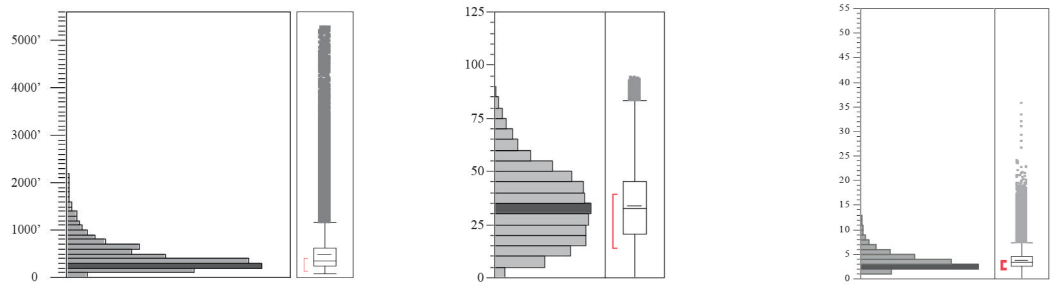
As a distribution, measures of scale – road segment length, block area, and block perimeter, illustrate positive skewness across a wide range, but despite this range, most are clustered around a more limited interval range. The interval mode of road segment length measures 200–300 feet and captures 18% of the road segments in the sample (Figure 3a), with the bins of the histogram distribution set at 100 feet. The interval mode of block area measures less than 20 acres and captures 82% of these blocks (Figure 4a), with the bins of the histogram distribution set at 20 acres. Of those, 71% measure less than 6 acres (Figure 4b). The interval mode of block perimeter measures 1,000 to 2,000 feet and captures 38% of these sampled blocks (Figure 5a), with the bins of the histogram distribution set at 1,000 feet. For those blocks measuring less than 3,000 feet in perimeter, the distribution in more normalized, and the interval mode measures 1,900 to 2,000 feet (Figure 5b), with the bins of the histogram distribution set at 100 feet.

Table 2
Quartile Measures of Length, Block Area, Block Perimeter, Metric Reach, and Directional Distance, as calculated for the Random Sample of Road Segments and Blocks

	Maximum	75.0%	Median	25.0%	Minimum	Interquartile Range
Road Segment Length (feet)	5278.6500	749.0590	412.4750	264.1210	72.1800	484.9380
Block Area (acres)	639.7180	12.0110	5.1643	2.8346	0.1197	9.1765
Block Perimeter (feet)	178,601.28	3511.2	2112.0	1536.48	269.28	1974.72
Metric Reach (miles)	94.3193	33.4969	19.6429	9.9434	0.0143	23.5535
Directional Distance	51.6138	5.5625	3.8521	2.7705	0.0000	2.7921



(a) Length (b) Metric Reach (c) Directional Distance

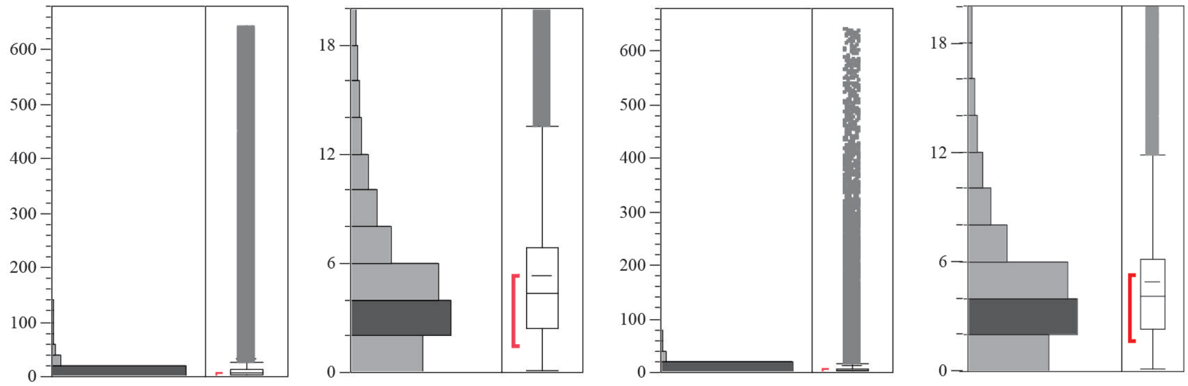


(d) Length
less than 15 mi from center

(e) Metric Reach
less than 15 mi from center

(f) Directional Distance
less than 15 mi from center

Figure 3
Distribution of Length, Metric Reach and Directional Distance for the Road Segments of the Random Sample



(a) .
Block Area

(b) .
Block Area,
less than 20 acres

(c) .
Block Area,
within 15mi of center

(d)
Block Area,
within 15mi of center,
less than 20 acres

Figure 4
Distribution of Block Area for the Blocks of the Random Sample

Measures of directness—those of directional distance— also illustrate positive skewness clustered around a narrower range, but measures of density—those of metric reach—illustrate a much greater range. With the bins of the histogram distribution set at one change in direction, the interval mode of directional distance measures more than 2 but less than 3 direction changes and captures 45% of these road segments (Figure 3c). As a contrast, the distribution of metric reach illustrates positive skewness across a broad range of measures. With the bins of the histogram distribution set at 5 miles, the interval mode of metric reach measures 5 to 10 miles of total reach and captures 17% of the road segments (Figure 3b).

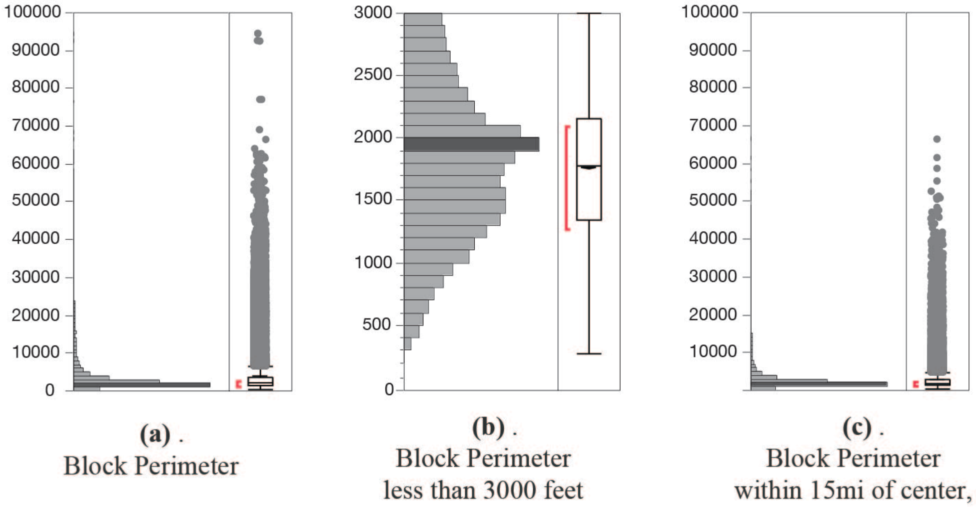


Figure 5
Distribution of Block Perimeter for the Blocks of the Random Sample

Notably, two effects from the sampling method could be affecting these results. First, local areas at the periphery of each city were sampled more frequently, and when compared to the city center, these local areas, or those of the sprawling suburban neighborhoods, tend to exhibit increases in their measures of scale with decreases in their measures of density and directness. Second, local areas at the center of each city tend to exhibit a greater number of road segments and blocks, lesser in their measures of scale though greater in their measures of density and directness. In either case, a simple distribution could misrepresent the data.

To test these effects, the distributions and frequencies are studied independently, dividing the sample into two subsets—those road segments and blocks within a 15-mile radius of the metropolitan center and those outside that radius. For those 235,353 road segments and 85,976 blocks within the 15-mile radius, the interval mode of length measures 200–300 feet and captures 21% of this subset (Figure 3d). [7] The interval mode of block area measures less than 20 acres, and

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[7] Though not discussed or shown in the illustrations, those road segments located within a ten-mile radius of a metropolitan center were also tested. Of these 161,067 road segments, the interval mode of length again measures 200–300 feet and captures 21% of this subset. For the remaining 423,494 road segments with a distance greater than

it captures 90% of this subset (Figure 4c). Of those blocks measuring less than 20 acres, the interval mode of block area measures 2 to 4 acres (Figure 4d). However, the distribution of metric reach is normal in its dispersion (Figure 3e). With bins of the histogram distribution set at 5 miles, the interval mode of metric reach measures 30–35 miles, capturing 10% of this subset; but notably, each of the bins measuring 15–20, 20–25, 25–30, 35–40, and 40–45 miles of metric reach also capture 10% of this subset.[8] For the remaining 349,208 road segments located more than 15-miles from the metropolitan center, the interval mode of length measures 200–300 feet and captures 16% of the subset. The interval mode of metric reach measures just 5–10 miles of metric reach and captures 24% of that subset. For the remaining 87,535 blocks located more than fifteen miles from the metropolitan center, the interval mode of block area measures less than 20 acres and captures 74% of this subset.

As expected for American cities, density is greatly affected by distance from the city center, but surprisingly, scale is not. Results demonstrate that the interval mode of metric reach is significantly greater, suggesting greater density for those road segments within 15-miles of the city center; but the interval mode of length and block area remain consistent for both subsets of data. Contrary then to the literature discussed in the introduction, these findings suggest that road segments at the center are not necessarily short, and those at the periphery are not necessarily long. Arguably then, concentrations of road segments or blocks at a metropolitan center do not unduly affect the results reported for the statistical measures of scale. This concentration must result of variability within the local areas themselves and not from either the greater sampling of local areas farther in their distance from the metropolitan center or the greater numbers of road segments and blocks at the center.

Thus, after examining the measures—their central tendency and frequency, most road segments encountered in these American cities measure less than 300 feet in length. Most blocks measure less than 20 acres, with most of those measuring less than 6 acres. And yet, most road segments are configured such that they require almost 3 changes in direction to navigate less than 10 miles of potential reach. As a benchmark reference: when road segments were drawn as street center-lines and blocks were calculated accordingly, the short side of a rectangular block for the New York City Commissioners' Plan of 1811 measured 260 feet, the long side measured 900 feet, yielding an average of 580 feet, the area for this same rectangular block measured 5.37 acres, and the perimeter measured 2,320 feet (0.4394 miles). For this local area of New York City, Peponis et al. (2007) reported a measure of 51.40 miles for metric reach and 1.91 for directional distance.

Comparing Measures to Suggested Guidelines

For this random sample of road segments and blocks, distributions of the measures of connectivity are shown in comparison first, to the more familiar, historically significant neighborhoods defining

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ten miles from a metropolitan center, the interval mode of length measures 200–300 feet and captures 17% of this subset.

[8] As with length, the road segments located within a 10–mile radius of the metropolitan center were also tested. The distribution is multimodal, but for these 161,067 road segments, the interval mode of metric reach measures 40–45 miles and captures 12% of this subset. Additional peaks are exhibited at 30–35 miles, 35–40 miles, and 45–50 miles, each capturing 11% of this subset. For the remaining 423,494 road segments with a distance greater than ten miles from the metropolitan center, the interval mode of metric reach measures 5–10 miles and captures 22% of this subset.

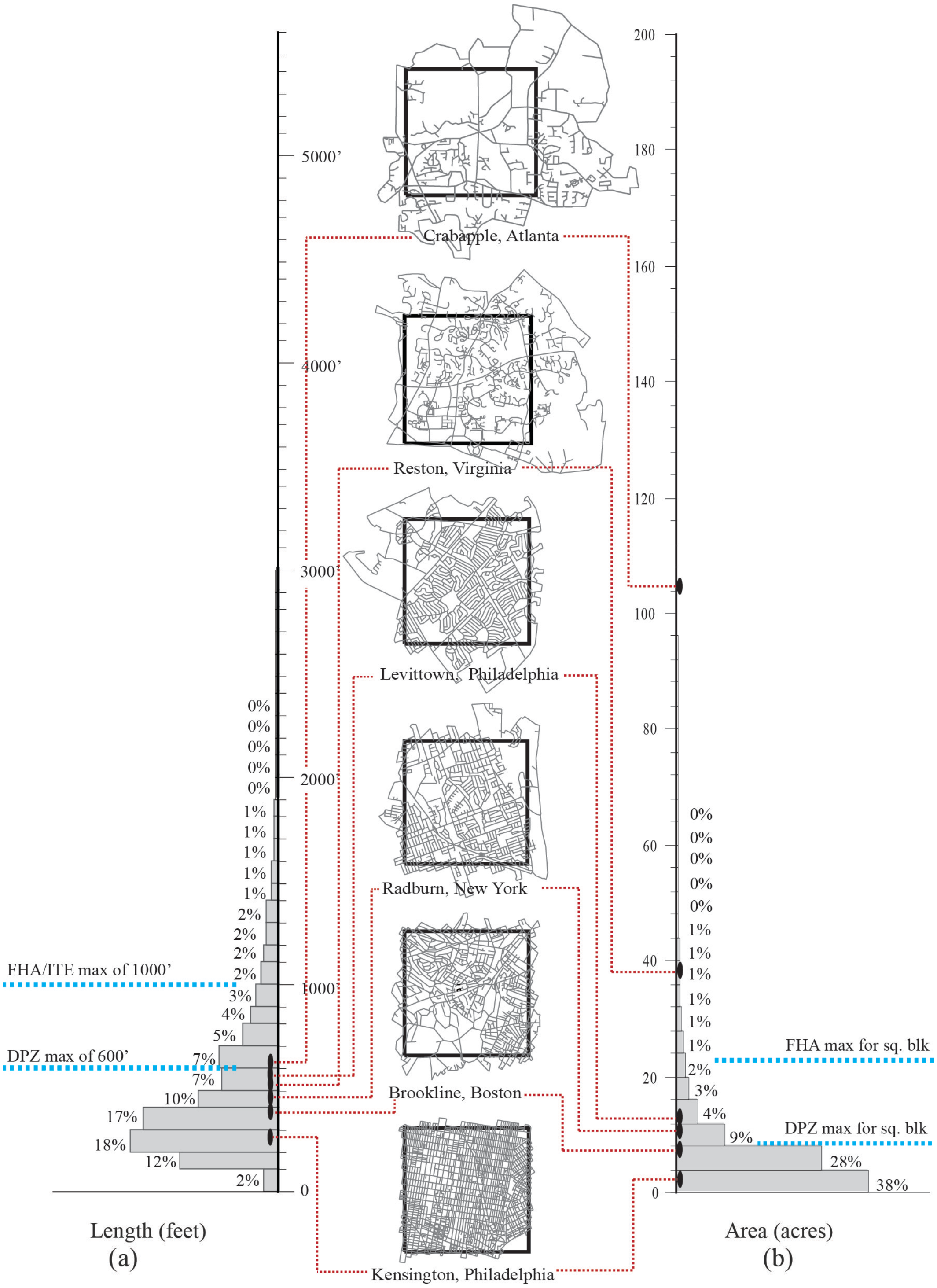
distinct periods of planning and transportation trends, second to those measures mandated in the regulatory frameworks, and lastly to the benchmarks suggested as guidelines from respected practitioners in the field. The local areas of Kensington (Philadelphia), Brookline (Boston), Radburn (New Jersey), Levittown (Philadelphia), Reston (Virginia, and Crabapple (Atlanta) were selected to capture the morphological characteristics of early gridded areas, late 19th century curvilinear suburbs, influences from the Garden City and City Beautiful movements, and finally those emerging cul-de-sac patterns of Edge Cities in the late 20th century. These local areas are often used as models to illustrate the intention of the suggested guidelines and they capture distinct urban morphologies. Their measures of road segment length, block area, block perimeter, metric reach, and directional distance are reported, for reference, in Table 3. As a mean, significant differences are illustrated between the measures of these local areas, but as a maximum, most exceed suggested guidelines.

Related to mandates by regulatory frameworks, the 1990 ITE standards suggested a maximum road segment length of 1,000 feet. Similarly, the work of Handy, Paterson, and Butler (2003) studied several new ordinances governing development and revealed that most ordinances interested in increasing density, walkability, and street connectivity mandated an average block face (or road segment length) measuring more than 300 but less than 600 feet. As a comparison, most road segments, as captured within this random sample, measure substantially less in their length than the maximum allowed (Figure 6). In fact, road segments within the most sprawling suburb examined by Peponis et al. (2007)—Crabapple (Atlanta) —came close to meeting the suggested standards for road segment length, though admittedly block area was substantially larger. This finding suggests a lack of interdependency between the measures of scale—that of road segment length and block area—despite previously illustrated correlations in the literature.

Table 3
Mean and Maximum of Length, Block Area, Block Perimeter, Metric Reach, and Directional Distance, as calculated Road Segments and Blocks in Local Areas of Historical Significance

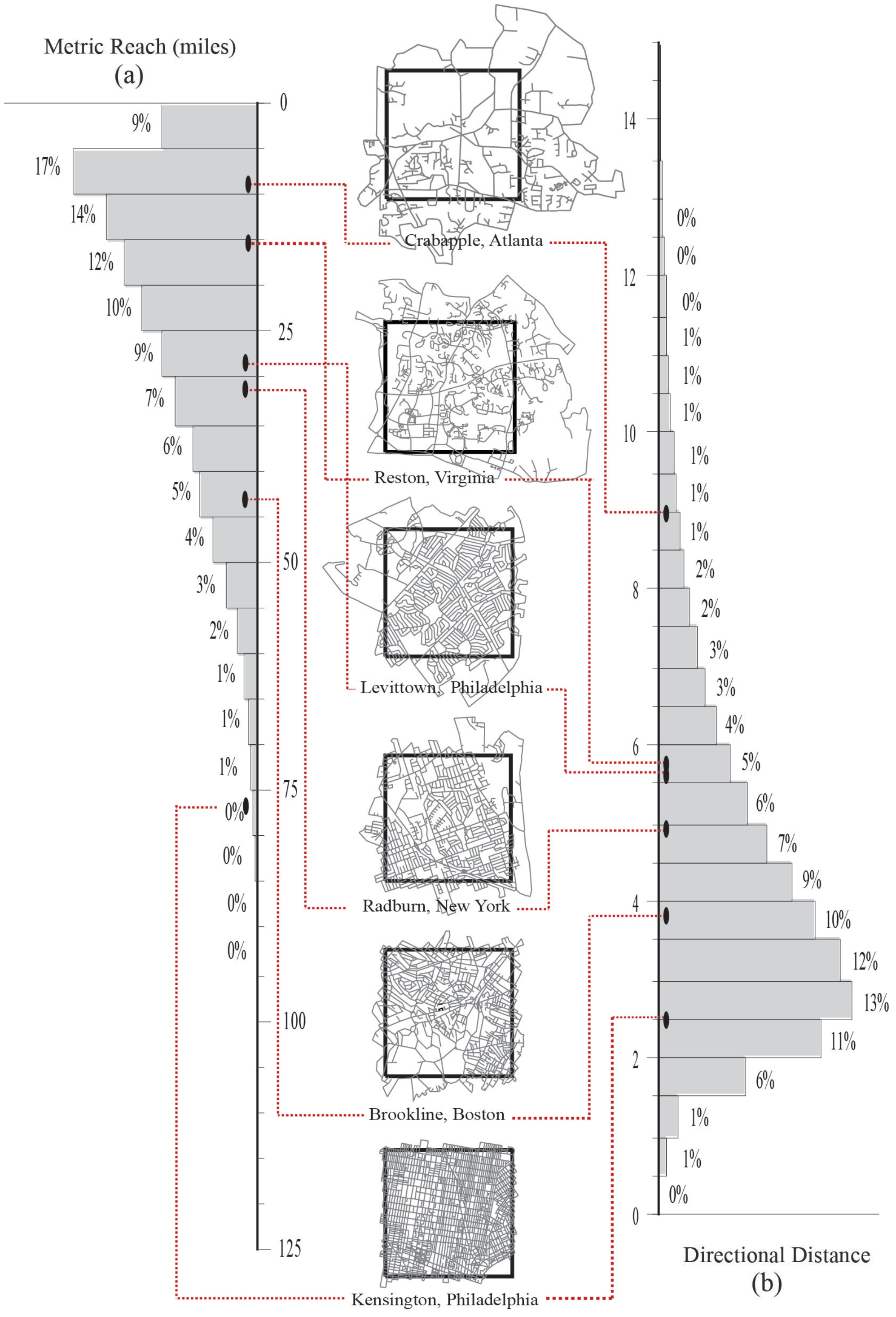
Local Area	**Mean of Road Segment Length (feet)**	**Max of Road Segment Length (feet)**	**Mean of Block Area (acre)**	**Max of Block Area (acre)**	**Mean of Block Perimeter (feet)**	**Max of Block Perimeter (feet)**	**Mean of Metric Reach at 1mi (miles)**	**Max of Metric Reach at 1mi (miles)**	**Mean of Directional Distance at 1 mi/10**	**Max Directional Dist. at 1 mi/10 degree (changes in direction)**
Kensington (Philadelphia)	286.40	1,205	2.19	16.64	1,340	4,451	77.80	92.70	2.52	6.23
Brookline (Boston)	375.22	2,844	7.50	171.52	2,283	13,079	43.96	60.42	4.90	11.92
Riverside (Chicago)	497.32	3,040	12.18	256.64	2,756	19,879	29.29	46.65	3.30	9.08
Levittown (Philadelphia)	556.32	2,809	13.05	310.40	3,514	21,606	28.70	41.51	5.67	10.61
Radburn (New Jersey)	438.06	5,260	10.80	517.76	2,762	35,983	31.02	49.36	3.85	11.87
Reston (Virginia)	530.44	3,833	37.88	1,098.88	4,288	44,378	15.13	25.95	8.99	20.53
Crabapple (Atlanta)	645.05	6,058	128.61	1,074.56	8,634	39,922	9.58	22.25	5.70	14.11

(Data for these historically and morphologically significant local areas was sourced from Haynie (2016))



(Data for these historically and morphologically significant local areas was sourced from Haynie (2016))

Figure 6
Distribution of Length and Area for the Random Sample of Road Segments and Blocks, Benchmarked Against Influential Local Areas in the Literature and Suggested Guidelines for Regulation



(Data for these historically and morphologically significant local areas was sourced fromHaynie (2016))

Figure 7
Distribution of Metric Reach and Directional Distance for the Random Sample of Road Segments and Blocks, Benchmarked Against Influential Local Areas in the Literature

As part of their checklist for traditional neighborhood development, Duany, Plater-Zyberk, and Speck (2000) suggested a maximum block face, or road segment length, of 600 feet. Comparatively, when the measures of this random sample are examined as a distribution and graphed against these suggested guidelines, a significant majority of the road segments, 65% in fact, measure less than 600 feet in length, and 82% of the blocks measure less than 20 acres in area, with 71% of those measuring less than 6 acres (Figure 6). And yet for metric reach, only 8% of the road segments measure more than 50 miles of potential reach. These results illustrate the discrepancy in the predictability of measures of scale to adequately describe connectivity and suggests that the use of measures of scale, by themselves, may not be suitable to achieve intended results.

Unexpectedly, when sampled randomly and with equitable probability, many of the road segments found within these American cities are quite reasonable in their measures of length, meeting and in many cases, exceeding, the suggested standards. Similarly, many of the blocks are quite reasonable in their measures of area and perimeter. In contrast, only 39% of the road segments captured more than 25 miles of metric reach; and 18% captured this reach in less than 2.5 changes in direction (Figure 7), suggesting significant circuitousness amid poor density.

Thus, one of the more important findings from this research illustrates that the most frequently encountered measures of road segment length and block area were substantially less than those suggested in regulatory policies, and yet measures of density and directness are still quite low. Statistically, given the demonstrated correlations of the measures (Peponis, Allen, Haynie, et al. (2007), shorter road segments and smaller blocks should yield higher measures of metric reach, but for the road segments within this random sample, this was not the case, suggesting poor connectivity for these reasonably scaled road segments. If most road segments and blocks meet the suggested guidelines of scale, measuring less than 600 feet in length and less than 6 acres in area, then why are the measures of density so low?

Concluding Remarks

Specific to this research, measures of road segment length, block area, block perimeter, metric reach, and directional distance—their central tendency, frequency and associated distributions—were examined to offer a fundamental sense of the scale, density and directness encountered in these American cities. It finds that that the most frequently encountered measures of road segment length, block area, and block perimeter were substantially less than those suggested in regulatory policies, and yet, the measures of density were still extremely low. Given these findings, policy makers should note that the measures of scale, when used in isolation, do not accurately characterize or comprehensively describe street connectivity, despite their current emphasis within research and practice. Mandating measures of scale to regulate the configuration of road segments within the urban form may or may not yield the current desired outcome of increased connectivity.

Additionally, this research demonstrates that measures of scale are not as powerful a descriptor of street connectivity as some of the more complex or composite measures tested, such as those of metric reach and directional distance. By definition, metric reach is a measure of density contingent on both scale and connectivity relative to the configuration of road segments. Thus, the measure of metric reach is highly influenced by not only the length of each road segment but its connection to the surrounding context as well. As a result, the measure of metric reach is a more accurate measure of street connectivity. If density is the gauge to define the quality of an environment, as suggested by Moudon (1986), then perhaps regulating measures of length, area, or perimeter are not sufficient. Clearly, given these findings, they are not guaranteed to yield intended results.

Perhaps our problem is not scale, as we've been trying to confront in practice, mandate through policy, and study in the literature, but rather one of configuration. If we wish to increase street connectivity, if we wish to "connect spatially separated spaces and to enable movement from one place to another" (Handy et al., 2003, p. 68), then we must focus on a measure of connectivity that inherently measures configuration. If we wish to "increase the number of connections and the directness of routes" (Handy et al., 2003, p. 68), then we must consider a measure that captures the circuitousness of a network relative to the potential distance available. Notably, metric reach and directional distance do both, and thus, they may be a more accurate and more appropriate descriptor of street connectivity, as intended by policy makers. Arguably, measures, like metric reach and directional distance—those that capture aspects of configuration relative to scale—may be necessary additions to the regulatory policies and suggested guidelines to insure intended results.

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